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ABSTRACT

This document contains a teacher's guide and student guide for a high school-level competency-based course in air conditioning and refrigeration (ACR) equipment electrical systems. Presented in the teacher's guide are the following: explanation of the instructional units' use; competency profile for recording students' performance of the tasks in each unit; national competencies correlated to the unit objectives, assignment sheets, and job sheets; a list linking unit tasks to the related academic workplace skills and competencies they are designed to reinforce; a list of required tools, equipment, and materials; and a list of the six references used to develop the publication. Presented next are the 15 units of instruction. Each unit contains some or all of the following: objective sheets, suggested activities, written test, unit evaluation activity, assignment sheet and written test answers, teacher supplements, transparency masters, information sheet, student supplements, and assignment sheets. The following topics are covered: fundamentals of electricity; tools, materials, and test instruments; electrical power; circuits, symbols, and diagrams; controls and protection devices; transformers and relays; thermostats; introduction to electric motors; split-phase motors; capacitors; capacitor motors; three-phase motors; troubleshooting ACR system electrical circuits; and ACR system wiring diagrams. The corresponding units in the student's guide contain some or all of the following: objective sheets, information sheets, student supplements, assignment sheets, and job sheets. (MN)

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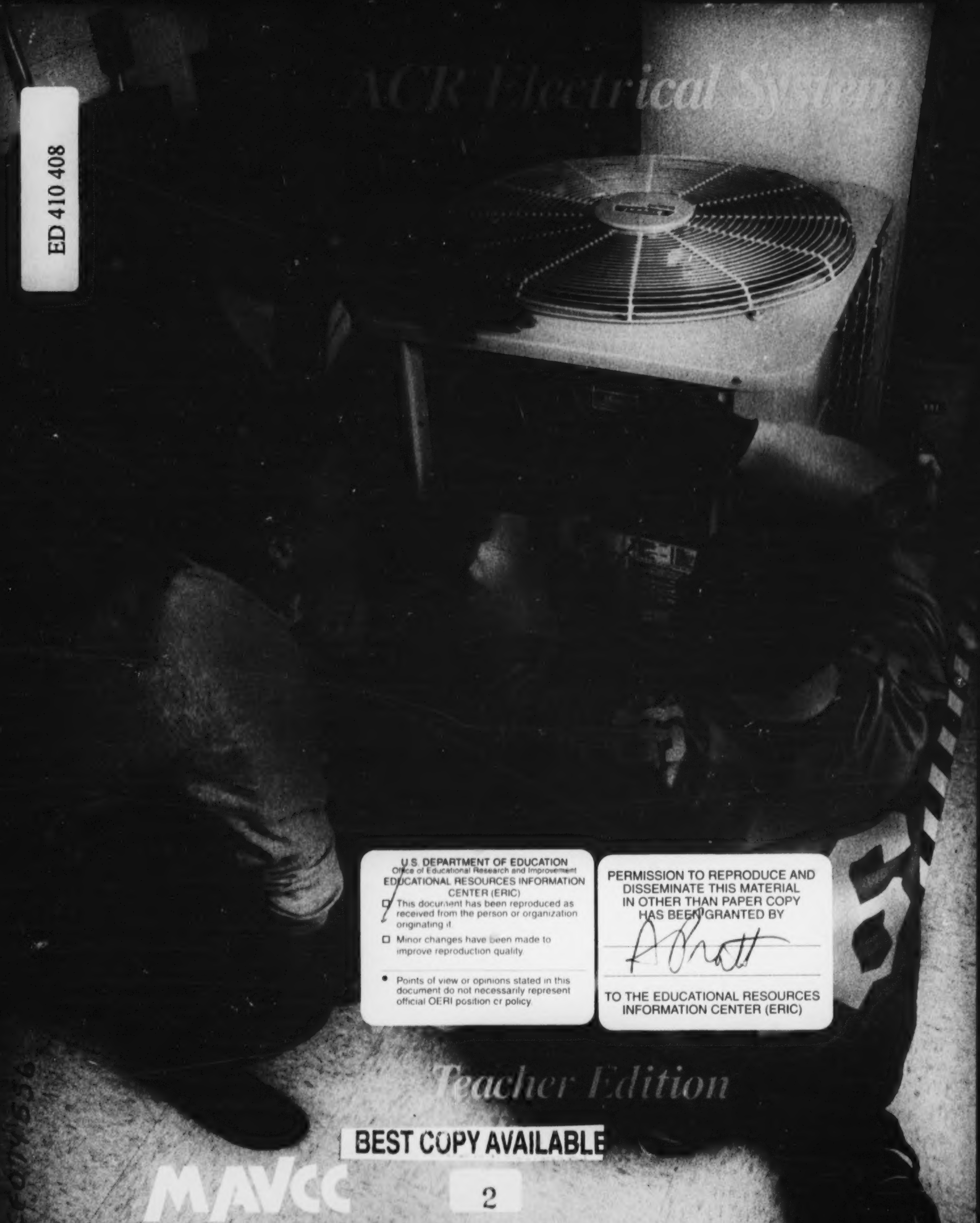
ACR Electrical System



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MAVCC
Multistate Academic and Vocational Curriculum Consortium

ACR Electrical Systems

Written by

Mark Clemons

Project Coordinated by

Dan Fulkerson
Curriculum Specialist

Developed by

The Multistate Academic and Vocational Curriculum Consortium, Inc.

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ACR Electrical Systems

Teacher Edition

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Disclaimer

This text presents information about ACR electrical systems and the tools, equipment, and procedures used to troubleshoot ACR system electrical circuits in equipment ranging from refrigerators and window air conditioners to all types of ACR system motors. The information is designed for presentation by an experienced instructor in a classroom/lab environment designed for the safety of students and equipment. Because training activities vary with local implementation, the writer and publisher disclaim liability for use of these materials for other than their intended purpose.

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Foreword

At both the component and system level, HVACR technicians who can efficiently solve electrical problems have better jobs and make better money. *ACR Electrical Systems* is designed to help students learn electrical troubleshooting by starting with the fundamentals of electricity and basic symbols, and then working with control circuitry, transformers, relays, thermostats, and the many kinds of motors used in the HVACR industry.

Another major element of the text concerns pictorials and ladder schematics, the "literature" of the HVACR industry. Troubleshooters must know how to read and interpret schematics, and even how to draw them. That is the major focus of *ACR Electrical Systems*. The text presents more than sixty well-designed problems that guide students step-by-step through the process of drawing a pictorial to show component relationships, fabricating a working model on a trainer to prove the circuit works, and then drawing a ladder schematic to show where and how components function. Problems have been carefully selected to reflect the same kinds of circuits found in a variety of HVACR equipment that students will maintain and service as professionals.

Because of its significance in customer relations, "Thermostats" is an important unit in this text. In fact, the thermostat is the most used customer/equipment interface in the HVACR industry. Students learn application techniques including how to set a heat anticipator. To help customers sleep comfortably and conserve energy, students learn how to program a setback thermostat for a residence; business setback programming is also included.

Students who successfully complete the assignment and job sheets in this text will attain the special skills it takes to be well-paid professionals. We hope instructors will apply their own special skills to localize and individualize the instruction, and motivate students with well-planned demonstrations.

Share your opinions about *ACR Electrical Systems* with other instructors and especially with MAVCC. Write us or give us a toll-free call at 1-800-654-3988. You can also reach our home page on the internet at http://www.mavcc.org.

Jean McEntire
Chair, Board of Directors
Multistate Academic and
Vocational Curriculum Consortium

Clark R. Harris
Executive Director
Multistate Academic and
Vocational Curriculum Consortium

Acknowledgments

The resource committee which met to review and revise MAVCC's *Air Conditioning and Refrigeration Electrical Components and Systems* recommended significant changes and additions that are reflected in this new text, *ACR Electrical Systems*. For their realistic assessment of changing training needs and their support of the project, MAVCC thanks those instructors and industry members who served on that resource committee.

Don Havens	Instructor, Metropolitan Vocational Center Little Rock, Arkansas
Harold Butler	Instructor, Delta-Quachita Regional Technical Institute West Monroe, Louisiana
Del Winston	Instructor, Northland Career Center Platte City, Missouri
Curt Neuharth	Instructor, Mitchell Technical Institute Mitchell, South Dakota
Jack Stewart	TULSAIR Tulsa, Oklahoma
Sherman Hanes	Instructor, Tulsa County AVTS Lemley Campus Tulsa, Oklahoma
Frank Greer	Instructor, O.T. Autry AVTS Enid, Oklahoma
Dave Stephenson	HVACR Consultant Broken Arrow, Oklahoma
James Bynum	Instructor, Port Neches-Groves High School Port Neches, Texas

Use of Introductory Materials

Introductory materials are included in the teacher edition only and contain useful information to assist administrators and teachers in planning for instruction.

In addition to the general information such as the table of contents, the following information is also included:

1. **Use of this publication**—Explains the components of a unit of instruction and how they should be used as part of the teaching/learning process.
2. **Competency profile**—Provides a record of student performance for each task included in a unit of instruction. This becomes a part of the student's permanent records and should be utilized when directing the student toward employment opportunities.
3. **National competencies**—Matches objectives, assignment sheets, and job sheets to national standards, as those standards are made available.
4. **Related academic and workplace skills list**—Classifies unit tasks (assignment sheets and job sheets) according to related academic and workplace skills and competencies being reinforced. Skill areas reflected by skill groups, subskills, and definitions have been matched with *What Work Requires of Schools: A SCANS Report for America 2000 and Workplace Basics: The Skills Employers Want.*
5. **Tools, equipment, and materials list**—Provides a comprehensive list of those items needed to successfully complete the assignment/job sheets and assists administrators/teachers in determining program costs.
6. **Reference list**—Provides a comprehensive list of resources used in the development of this publication.

Use of This Publication

Instructional Units

ACR Electrical Systems contains 15 units of instruction. Each instruction unit in a teacher edition includes some or all of the following basic components: objective sheet, suggested activities, answers to assignment sheets, answers to the written test, written test, unit evaluation form, teacher supplements, transparency masters, information sheet, student supplements, assignment sheets, and job sheets.

All of the unit components focus on observable and measurable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help to determine the following:

- Amount of materials that can be covered in each class period.
- Skills that must be demonstrated.
- Amount of class time needed for demonstrations.
- Amount of time needed for student practice.
- What must be obtained for supplementary materials such as other printed materials, video tapes, CD-ROMs, or other equipment and supplies.
- Resource people who must be contacted.

Objective Sheet

Each unit of instruction is based on performance objectives stated generally in the unit objective as performance activities. Specific objectives provide the student with the information needed to reach the unit objective and successfully complete the course.

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer questions concerning performance requirements, and also help determine teaching strategies and instructional methods.

As teachers plan instruction, they should feel free to modify, delete, or add objectives in order to meet the needs of the student and the community. When objectives are added or modified, the teacher should supply students with the information sheet materials or assignment or job sheets and criterion-referenced test items.

Suggested Activities

This component is included only in the teacher edition. The suggested activities assist teachers in the preparation stage by providing an instructional plan, teaching suggestions, and a list of supplemental resources. Ways to integrate academic and workplace skills have been included in the suggestions, and skill areas have been noted in boldface type. A table of academic and workplace skills is also provided on page xxv. Before teaching each unit, the teacher should read the suggested activities and decide how each objective can best be taught. Teachers should also allow time to obtain supplemental materials, prepare audiovisual or other teaching aids, and contact outside resources.

References used in the development of each unit are listed in suggested activities along with supplemental resources. These materials can be used to supplement teacher expertise and to help students with special interests in specific areas of instruction.

Instructions for evaluating student job sheet performance are also included in the suggested activities. Teachers should select and discuss with students the rating scale that will be used.

Answers to Assignment Sheets and Answers to Written Test

Answers to both the assignment sheets and written test are provided to save instructors time in properly evaluating student achievement.

Written Test

This component provides a criterion-referenced test question for every cognitive objective in the unit of instruction. The test appears in the teacher edition, but duplication is permitted for student use. If the objective sheet is modified, such changes should be noted on the written test. It is also recommended that the test be divided into shorter tests covering three or four objectives and given soon after the objectives have been taught. The test may also be used as a pretest to identify student skill level, and items from individual units can be combined for a final test at the end of a term or semester.

Unit Evaluation

This sheet provides teachers with a record of student performance at the end of each unit. It includes space for assignment sheet ratings, job sheets ratings, written test scores, both pretest and posttest, and an area for teacher comments. The unit evaluation is in the teacher edition only, but it may be duplicated as needed for placement in student records or portfolios.

Teacher Supplements

This component is in the teacher edition only and designed to be used for a variety of purposes: to provide the teacher with higher level materials to challenge advanced students, to provide remedial information or practice that may assist less-advanced students, and to provide the teacher with state-of-the art information not readily available from other sources. Teacher supplements may be duplicated as needed for student use.

Transparency Masters

Transparency masters are in the teacher edition only. They need to be copied and used on overhead projectors to help enhance specific objectives in the text. Charts, schematics, pictorials, and schematics serve to visually reinforce specific objectives.

Information Sheet

The information sheet provides the content essential for meeting the cognitive objectives of the unit. It is an excellent guide for presenting the tools, materials, and processes necessary for a student to complete the unit performance skills. The information sheet has generous margins that can be used for notes to help both teachers and students clarify materials and localize and personalize objectives.

Student Supplements

Student supplements may be part of the student edition. They are frequently charts or tables that students may need to access while completing assignment or job sheets. The supplement may also present optional materials of interest or items such as troubleshooting charts that students may retain for reference in later study or in the workplace.

Assignment Sheets

Assignment sheets are mostly pencil and paper activities that permit students to practice with math, work with reference materials, or generally make a practical application of items in the objective sheets. The assignment sheets help teachers objectively evaluate skills that are sometimes difficult to assess otherwise, and spot problem areas where a student may require review or special help.

Job Sheets

The job sheets are the activities that provide the student with hands-on applications to demonstrate their abilities to apply what they have learned from the information sheet. The sheets detail a list of tools and equipment the student will require and tell the student exactly how the psychomotor performance will be rated. Teachers should demonstrate job sheets, provide appropriate materials to work with, and insure a safe classroom/lab environment in which to complete the activity. Job sheets are a critical part of each unit because they provide potential employers with a picture of skills being taught during training and are essential to the school-to-work transition.

Disseminating Material

To retain student interest, materials may be passed out a page at a time or a unit at a time. Some programs may require students to provide three-ring binders or folders so the material can be kept in a unit-by-unit order. This provides a student the convenience of taking materials home for study. In some programs, materials are filed by unit and passed out to the student as they are needed.

For best results, use the materials for motivation. Make sure each student gets the complete materials and that the materials become the student's property to take home at the successful end of the course. Many students like to retain materials because they find them valuable reference materials when they move on to a career.

National VICA Competencies
for
ACR Electrical Systems

A comprehensive list of national VICA competencies for air conditioning is presented in MAVCC's *Fundamentals of Air Conditioning and Refrigeration*. The competencies presented here are those directly related to electrical and electronic elements of the ACR industry. These competencies are cross-referenced to appropriate objectives, assignment sheets, and job sheets to help administrators and instructors with program articulation.

Unit 1: Fundamentals of Electricity

VICA Section	VICA Competency	Component & Content	Notes
F: Electricity	1. Demonstrate safe operating procedures. 2. Demonstrate knowledge of Ohm's and Watt's Laws. 4. Demonstrate and apply knowledge of AC circuits. 6. Demonstrate and apply knowledge of series/parallel circuits.	Objective 14 presents concept and elements of safely grounding circuits. Objectives 17, 18, 19, & 20 require student to write equations for Ohm's Law, and use the law to find values in series, parallel, and series-parallel circuits. Assignment Sheet 1 requires student to determine unknown values in resistive circuits.	Objective 1 presents terms and definitions to promote subject area literacy.

Unit 2: Tools, Materials, and Test Instruments

F: Electricity	14. Install wire nuts and special wiring connections. 15. Install solder connections and heat-shrink tubing. 16. Test fuses, receptacles, and circuit breakers.	Objective 4 presents five types of wiring connections: screw & clamp-on terminals, splices & soldered splices, wire nuts, and terminal blocks. Job Sheet 2 requires student to splice wires using wire nuts. Job Sheet 1 requires student to solder terminals onto wires. Job Sheet 3 requires student to use digital and analog voltmeters to check power sources. Job Sheet 4 requires student to use an ohmmeter to check continuity of fuses. Job Sheet 5 requires student to determine the resistance of resistors.	Objective 1 presents terms and definitions to promote subject area literacy.

National VICA Competencies

Unit 2: Tools, Materials, and Test Instruments (Continued)

VICA Section	VICA Competency	Component & Content	Notes
F: Electricity	2. Use motor test equipment. 18. Use amp-probe meter.	Job Sheet 6 requires student to use an ohmmeter to identify terminals and electrical conditions of a hermetic compressor. Job Sheet 7 requires student to use an ammeter to read start and run amperage of a motor.	Assignment Sheet 1 requires student to read a voltmeter. Assignment Sheet 2 requires student to read an ammeter. Assignment Sheet 3 requires student to read an ohmmeter.

Unit 3: Electrical Power

F: Electricity	7. Demonstrate and apply knowledge of electrical distribution. 17. Use a wattage meter.	Objectives 2 through 6 present characteristics of electrical power generation including distribution and delivery with the use of transformers and power supplies. Assignment Sheet 2 requires student to read an electric watt- hour meter. Job Sheet 1 requires student to use a wattmeter and an ammeter to determine watts.	Objective 1 presents terms and definitions to promote subject area literacy. Assignment Sheet 1 requires student to use Watt's Law to determine power.

Unit 4: Circuits, Symbols, and Diagrams

F: Electricity	10. Demonstrate and apply knowledge of wiring diagrams, schematics, and electrical symbols.	Job Sheet 1 requires student to draw pictorials, fabricate working models, and draw ladder schematics for basic series and parallel circuits. Job Sheet 2 requires student to draw pictorials, fabricate working models, and draw ladder schematics for series-parallel circuits. Job Sheet 3 requires student to draw pictorials, fabricate working models, and draw ladder schematics for circuits with varied loads and switching.	Objective 1 presents terms and definitions to promote subject area literacy.

National VICA Competencies

Unit 5: Controls and Protection Devices

VICA Section	VICA Competency	Component & Content	Notes
F: Electricity	9. Demonstrate and apply knowledge of circuit protection 28. Demonstrate knowledge of relays. 29. Demonstrate knowledge of pressure-operated switches and solid-state switches. 26. Demonstrate knowledge of safety interlocks.	Objectives 2 through 6 present controls and their applications, including types of controls, control systems, and switch configurations. Objective 9 presents types of protection devices and how/where they are used in circuits. Objectives 10, 11, & 12 present overcurrent protection devices, pressure-actuated protection devices, and motor protection devices. Job Sheet 1 requires student to draw pictorials, fabricate working models, and draw ladder schematics for shunt circuits with one SPST switch. Job Sheet 2 requires student to draw pictorials, fabricate working models, and draw ladder schematics for circuits with 3-way switches. Job Sheet 3 requires student to draw pictorials, fabricate working models, and draw ladder schematics for circuits with 3-way and 4-way switches. Job Sheet 4 requires student to draw pictorials, fabricate working models, and draw ladder schematics for circuits with safety switches.	Objective 1 presents terms and definitions to promote subject area literacy.

Unit 6: Transformers and Relays

F: Electricity	8. Demonstrate knowledge of electrical components. 28. Demonstrate knowledge of relays.	Objective 2 presents how a transformer works. Objective 5 presents relay components and uses. Objective 7 presents control relays and contactors. Objective 8 presents relays, contactors, and their switching arrangements. Objectives 9 through 14 present motor starting relays and operations, current relay operations, potential relay operations, time-delay relay operations, and electronic controls for timed functions. Assignment Sheet 1 requires student to identify selected relays. Job Sheet 1 requires student to draw pictorials, fabricate working models, and draw ladder schematics for circuits with basic relays.	Objective 1 presents terms and definitions to promote subject area literacy.

National VICA Competencies

Unit 6: Transformers and Relays (Continued)

VICA Section	VICA Competency	Component & Content	Notes
F: Electricity		Job Sheet 2 requires student to draw pictorials, fabricate working models, and draw ladder schematics for circuits with dual relays. Job Sheet 3 requires student to draw pictorials, fabricate working models, and draw ladder schematics for circuits with special applications. Job Sheet 4 requires student to draw pictorials, fabricate working models, and draw ladder schematics for circuits with multiple relays. Job Sheet 5 requires student to check current relays with an ohmmeter. Job Sheet 6 requires student to check potential relays with an ohmmeter. Job Sheet 7 requires student to check current relays with an ohmmeter and a voltmeter.	Objective 1 presents terms and definitions to promote subject area literacy.
	50. Install solid-state devices.	Job Sheet 8 requires student to check a potential relay with an ohmmeter and a voltmeter. Job Sheet 9 requires student to install a solid-state time-delay relay.	

Unit 7: Thermostats

F: Electricity	8. Demonstrate and apply knowledge of electrical components. 32. Install thermostats.	Objectives 2 through 7 present components of heating/cooling thermostats including heating and cooling anticipation. Objective 8 presents problems encountered when installing heating/cooling thermostats. Objective 9 presents multistage thermostats. Objective 10 presents subbase applications. Objectives 13 & 14 present electronic thermostats and benefits of solid-state thermostats. Job Sheet 1 requires student to install a wall thermostat with heat anticipation. Job Sheet 2 requires student to replace a thermostat with an electronic programmable thermostat. Job Sheet 3 requires student to program a programmable thermostat.	Objective 1 presents terms and definitions to promote subject area literacy.

National VICA Competencies

Unit 8: Introduction to Electric Motors

VICA Section	VICA Competency	Component & Content	Notes
F: Electricity	56. Demonstrate ability to identify motors, i.e., size, rating, application, type, and servicing. 57. Identify motor components. 60. Identify use of mounting support and brackets. 62. Demonstrate knowledge of AC/DC motors. 34. Install motor speed controls. 58. Demonstrate knowledge of troubleshooting and apply motor diagnosing techniques.	Objectives 2 and 3 present types of electric motors and their applications. Objective 11 presents motor data plate information and how to find and use it. Objective 8 presents AC motor components and functions. Objective 10 presents motor mounts and applications. Objectives 4, 5, & 7 present AC/DC motors and electrically commutated motors. Objectives 12 through 14 present pulleys, pulley selection, and V-belts and V-belt selection. Assignment Sheet 1 requires student to use a pulley selection chart. Job Sheet 1 requires student to replace a missing V-belt, adjust tension, and check motor operation. Objective 15 presents troubleshooting electric motors. Assignment Sheet 2 requires student to solve electric motor problems by referencing a troubleshooting chart.	Objective 1 presents terms and definitions to promote subject area literacy.

Unit 9: Shaded-Pole Motors

F: Electricity	56. Demonstrate ability to identify motors i.e., size, rating, type, and servicing. 57. Identify motor components. 58. Demonstrate knowledge of troubleshooting and apply motor diagnosing techniques.	Objectives 2 through 5 present shaded-pole motor applications, construction, speed control, and rotation. Objective 6 presents shaded-pole motor troubleshooting. Job Sheet 1 requires student to disassemble, inspect, clean, reassemble, and check shaded-pole motor operations.	Objective 1 presents terms and definitions to promote subject area literacy.

Unit 10: Split-Phase Motors

F: Electricity	56. Demonstrate ability to identify motors, i.e., size, rating, type, and servicing. 57. Identify motor components.	Objectives 2 through 5 present characteristics and applications of split-phase motors, their construction, starting mechanisms and wiring. Objective 6 presents split-phase motor troubleshooting. Job Sheet 1 requires student to wire a single-voltage, split-phase motor to an AC power source. Job Sheet 2 requires student to wire a dual-voltage, split-phase motor for 120 VAC.	Objective 1 presents terms and definitions to promote subject area literacy.

National VICA Competencies

Unit 10: Split-Phase Motors (Continued)

VICA Section	VICA Competency	Component & Content	Notes
F: Electricity	58. Demonstrate knowledge of troubleshooting and apply motor diagnosing techniques.	Job Sheet 3 requires student to wire a dual-voltage, split-phase motor for 208/240 VAC. Job Sheet 4 requires student to disassemble, inspect, clean, reassemble, and check split-phase motor operation.	Objective 1 presents terms and definitions to promote subject area literacy.

Unit 11: Capacitors

F: Electricity	61. Demonstrate knowledge of mechanical and solid-state starting devices. 52. Install motor starting devices. 58. Demonstrate knowledge of troubleshooting and apply motor diagnosing techniques.	Objectives 2 through 6 present capacitor applications, construction and operation, and types. Objective 7 presents grouping capacitors. Assignment Sheet 1 requires student to calculate ratings of grouped capacitors. Job Sheet 1 requires student to check capacitors with an analog ohmmeter. Job Sheet 2 requires student to check capacitors with a capacitor analyzer.	Objective 1 presents terms and definitions to promote subject area literacy.

Unit 12: Capacitor Motors

F: Electricity	61. Demonstrate knowledge of mechanical and solid-state starting devices.	Objectives 2 and 3 present how capacitor affect motors and how capacitors are applied to motors. Objective 4 presents characteristics and applications of CS (Capacitor Start- Induction Run) motors. Objective 5 presents characteristics and applications of PSC (Permanent Split-Capacitor) motors. Objective 6 presents characteristics and applications of CSR (Capacitor Start-Capacitor Run) motors. Objective 8 presents troubleshooting capacitor motor start components. Assignment Sheet 1 requires student to draw wiring for a CS motor with a current relay. Assignment Sheet 2 requires student to draw connecting wiring for a PSC motor. Assignment Sheet 3 requires student to draw connecting wiring for a PSC motor.	Objective 1 presents terms and definitions to promote subject area literacy.

National VICA Competencies

Unit 12: Capacitor Motors (Continued)

VICA Section	VICA Competency	Component & Content	Notes
F: Electricity	61. Demonstrate knowledge of mechanical and solid-state starting devices. 58. Demonstrate knowledge of troubleshooting and apply motor diagnosing techniques.	Job Sheet 1 requires student to wire a CS compressor with a current relay. Job Sheet 2 requires student to wire a PSC motor. Job Sheet 3 requires a student to wire a CSR compressor motor. Job Sheet 4 requires student to disassemble, inspect, clean, reassemble and check operation of a PSC compressor motor. Job Sheet 5 requires student to use a hermetic analyzer to start, reverse, and check operation of a PSC compressor motor. Job Sheet 6 requires student to install a hard start kit.	Objective 1 presents terms and definitions to promote subject area literacy.

Unit 13: Three-Phase Motors

F: Electricity	56. Demonstrate ability to identify motor, i.e., size, rating, application, type, and servicing. 58. Demonstrate knowledge of troubleshooting and apply motor diagnosing techniques.	Objectives 2 and 3 present three- phase motor characteristics, applications, and construction. Assignment Sheet 1 requires student to draw connecting wiring for wye wound and delta wound dual-voltage motors. Job Sheet 1 requires student to wire a dual-voltage, three-phase motor, reverse rotation, and check operation.	Objective 1 presents terms and definitions to promote subject area literacy.

Unit 14: Troubleshooting ACR System Electrical Circuits

F: Electricity	56. Demonstrate ability to identify motor, i.e., size, rating, application, type, and servicing. 58. Demonstrate knowledge of troubleshooting and apply motor diagnosing techniques.	Objectives 2 and 3 present three- phase motor characteristics, applications, and construction. Assignment Sheet 1 requires student to draw connecting wiring for wye wound and delta wound dual-voltage motors. Job Sheet 1 requires student to wire a dual-voltage, three-phase motor, reverse rotation, and check operation. Objectives 2 through 4 present guidelines for general troubleshooting of electrical circuits, identifying components and their operation, and how to select the right test meters for troubleshooting.	Objective 1 presents terms and definitions to promote subject area literacy.

National VICA Competencies

Unit 14: Troubleshooting ACR System Electrical Circuits (Continued)

VICA Section	VICA Competency	Component & Content	Notes
F: Electricity	58. Demonstrate knowledge of troubleshooting and apply motor diagnosing techniques. 6. Demonstrate and apply knowledge of series-parallel circuits.	Objective 5 through 8 present guidelines for using voltmeters, ohmmeters, and ammeters and how to apply the hopscotch method of troubleshooting. Objective 9 presents ways to check for shorts and grounds. Objectives 10 and 11 present troubleshooting techniques and how to use jumpers. Assignment Sheet 1 requires student to identify electrical components on ACR system diagrams. Assignment Sheet 2 requires student to identify component operations on ACR system electrical diagrams. Assignment Sheet 3 requires student to select test instrument and procedures for specific ACR troubleshooting. Assignment Sheet 4 requires student to solve ACR electrical problems based on customer complaints. Job Sheet 1 requires student to troubleshoot series electrical circuits on selected ACR equipment. Job Sheet 2 requires student to troubleshoot parallel electrical circuits on selected ACR equipment. Job Sheet 3 requires student to troubleshoot series-parallel circuits on selected ACR equipment.	Objective 1 presents terms and definitions to promote subject area literacy.

Unit 15: ACR System Wiring Diagrams

F: Electricity	10. Demonstrate and apply knowledge of wiring diagrams, schematics, and electrical symbols.	Objective 2 presents guidelines for drawing system diagrams. Objectives 3 through 5 present ACR components and symbols, ACR switches and symbols, and solid-state components and symbols. Assignment Sheet 1 requires student to draw wiring diagrams for a refrigerator with a coil-type current relay.	Objective 1 presents terms and definitions to promote subject area literacy.

National VICA Competencies

Unit 15: ACR System Wiring Diagrams (Continued)

VICA Section	VICA Competency	Component & Content	Notes
F: Electricity	10. Demonstrate and apply knowledge of wiring diagrams, schematics, and electrical symbols.	Assignment Sheet 2 requires student to draw wiring diagrams for a refrigerator with a solid-state start relay. Assignment Sheet 3 requires student to draw wiring diagrams for a window air conditioner. Assignment Sheet 4 requires student to draw wiring diagrams for a standard upflow gas furnace. Assignment Sheet 5 requires student to draw wiring diagrams for a standard downflow gas furnace. Assignment Sheet 6 requires student to draw wiring diagrams for a multiposition gas furnace with an integrated control board. Assignment Sheet 7 requires student to draw wiring diagrams for a condensing unit. Assignment Sheet 8 requires student to draw wiring diagrams for an electric furnace. Assignment Sheet 9 requires student to draw wiring diagrams for a condensing unit and an air handler. Assignment Sheet 10 requires student to draw a ladder schematic for a domestic refrigerator. Job Sheet 1 requires student to observe a domestic refrigerator and draw a ladder schematic of its electrical circuits. Job Sheet 2 requires student to observe a window air conditioner and draw a ladder schematic of its electrical circuits. Job Sheet 3 requires student to observe a heating/cooling system with 24V controls and draw a ladder schematic of its electrical circuits.	Objective 1 presents terms and definitions to promote subject area literacy.

SCANS Foundation Skills and Competencies

Skill Groups	Subskills	Definitions
Basic Skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Writing	Communicating a thought, idea or fact in written form in a clear, concise manner.
	Arithmetic/Mathematics	Performing basic computations, applying, estimating, and reasoning skills, and solving practical problems using a variety of mathematical techniques.
	Science	Applying knowledge learned through study or practice that is based on scientific principles as they relate to specific tasks.
	Listening	Receiving, interpreting, and responding to verbal messages and other cues.
	Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
Thinking Skills	Creative thinking	Using imagination to generate new ideas.
	Decision making	Specifying goals and constraints, generating alternatives, considering risks and evaluating and choosing the best alternative.
	Problem solving Critical thinking	Recognizing and defining problems, devising and implementing plan of action, and tracking and evaluating results.
	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
	Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills.
	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
Personal Management Skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
	Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Career awareness, development, and mobility	Assessing self accurately, setting personal goals, establishing and implementing a plan, and monitoring progress.
	Integrity/honesty	Choosing an ethical course of action when faced with making a decision that may break with personal or societal values and recognizing the impact of violating these beliefs and codes on an organization, self, and others.
	Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of culture.
Resources	Time	Selecting relevant, goal-related activities, ranking them in order of importance, allocating time, and understanding, preparing, and following schedules.

SCANS Foundation Skills and Competencies

Skill Groups	Subskills	Definitions
Resources (Cont)	Money	Using or preparing budgets, making forecasts, keeping records, and making adjustments to meet objectives.
	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Human resources	Assessing skills and distributing work accordingly; evaluating performance and providing feedback.
Interpersonal Skills	Teamwork	Working cooperatively with others to reach a common goal.
	Coaching	Helping others learn new skills.
	Leadership	Communicating ideas to justify position, accepting responsibility for others, and encouraging, persuading, convincing, or otherwise motivating an individual or group.
	Negotiation	Resolving conflict between two or more individuals through discussion and compromise.
	Customer service	Working and communicating with customers to satisfy their expectations.
	Cultural diversity	Working well with men and women and with a variety of ethnic, social, or educational backgrounds.
Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
	Organization and storage	Organizing, processing, and maintaining written or computerized records and other forms of information in a systematic way.
	Interpretation	Selecting and analyzing information and communicating the results to others.
	Processing	Using computers to acquire, organize, analyze, and communicate information.
Systems	Interrelationships	Knowing how social, organizational, and technological systems work and operate effectively.
	Monitoring	Distinguishing trends, predicting impact of actions on system operations, diagnosing deviations in system performance and correcting malfunctions.
	Modification and design	Making suggestions to modify existing systems to improve products or services, and developing new or alternative systems.
Technology	Selection	Choosing procedures, tools, or equipment, including computers and related technology.
	Application	Demonstrating proper procedures for setting up and operating equipment.
	Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies.

ACR Electrical Systems

Competency Profile

Name: ________________________________

Directions: Evaluate the student using the rating scale below. Write a number to indicate the degree of competency achieved. Each rating descriptor focuses on a level of student performance. The written test score line is provided for optional teacher use.

Option A

Rating scale: 4—Skilled—Can perform job with no additional training.
3—Moderately skilled—Has performed job during training; limited additional training may be required.
2—Limited skill—Has performed job during training; additional training is required to develop skill.
1—Unskilled—Is familiar with process, but is unable to perform job.
0—No exposure—No information or practice during training; complete training required.
NA—Not applicable.

Option B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

Unit 1: Fundamentals of Electricity

____ 1. Convert electrical measurements to basic units.
____ 2. Use Ohm's Law to determine unknown values in resistive circuits.
____ 3. ____________________
____ 4. Written Test Score

Unit 2: Tools, Materials, and Test Instruments

____ 1. Read a voltmeter.
____ 2. Read an ammeter.
____ 3. Read an ohmmeter.
____ 4. Identify start, run, and common terminals and draw the windings of a single-phase motor.
____ 5. Solder terminals onto wires.
____ 6. Splice wires using wire nuts.
____ 7. Use digital and analog meters to check power sources.
____ 8. Use an ohmmeter to check continuity of fuses.
____ 9. Use an ohmmeter to determine the resistance of resistors.
____ 10. Use an ohmmeter to identify terminals and electrical conditions of a hermetic compressor.
____ 11. Use an ammeter to read start and run amperage of a motor.
____ 12. ____________________
____ 13. Written Test Score

Unit 3: Electrical Power

____ 1. Use Watt's Law to determine power.
____ 2. Read an electric watt-hour meter.
____ 3. Use a wattmeter and an ammeter to determine watts.
____ 4. ____________________
____ 5. Written Test Score

Unit 4: Circuits, Symbols, and Diagrams

____ 1. Draw pictorials, fabricate working models, and draw ladder schematics for basic series and parallel circuits.
____ 2. Draw pictorials, fabricate working models, and draw ladder schematics for series-parallel circuits.
____ 3. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with varied loads and switching.
____ 4. ____________________
____ 5. Written Test Score

Unit 5: Protection Devices

____ 1. Draw pictorials, fabricate working models, and draw ladder schematics for shunt circuits with one SPST switch.
____ 2. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with 3-way switches.
____ 3. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with 3-way and 4-way switches.
____ 4. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with safety switches.
____ 5. Draw a pictorial, fabricate a working model, and draw a ladder schematic of a basic refrigeration circuit.
____ 6. ____________________
____ 7. Written Test Score

Unit 6: Transformers and Relays

____ 1. Identify selected relays.
____ 2. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with basic relays.
____ 3. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with dual relays.
____ 4. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with special applications.
____ 5. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with multiple relays.
____ 6. Check current relays with an ohmmeter.
____ 7. Check potential relays with an ohmmeter.
____ 8. Check current relays with an ohmmeter and a voltmeter.
____ 9. Check a potential relay with an ohmmeter and a voltmeter.
____ 10. Install a solid-state time-delay relay.
____ 11. ____________________
____ 12. Written Test Score

Unit 7: Thermostats

____ 1. Install a wall thermostat and determine heat anticipation.
____ 2. Replace a thermostat with an electronic programmable thermostat.
____ 3. Program a programmable thermostat.
____ 4. ____________________
____ 5. Written Test Score

Competency Profile

Unit 8: Introduction to Electric Motors

____ 1. Use a pulley selection chart.
____ 2. Solve electric motor problems.
____ 3. Replace a missing V-belt, adjust tension, and check motor operation.
____ 4. ____________________
____ 5. Written Test Score

Unit 9: Shaded-Pole Motors

____ 1. Wire a shaded-pole motor to a voltage supply.
____ 2. Disassemble, inspect, clean, reassemble and check operation of a shaded-pole motor.
____ 3. ____________________
____ 4. Written Test Score

Unit 10: Split-Phase Motors

____ 1. Wire a split-phase motor to an AC power source.
____ 2. Wire a dual-voltage, split-phase motor for 120 VAC.
____ 3. Wire a dual-voltage, split-phase motor for 208/240 VAC.
____ 4. Disassemble, inspect, clean, reassemble, and check operation of a split-phase motor.
____ 5. ____________________
____ 6. Written Test Score

Unit 11: Capacitors

____ 1. Calculate rating of grouped capacitors.
____ 2. Check capacitors with an analog ohmmeter.
____ 3. Check capacitors with a capacitor analyzer.
____ 4. ____________________
____ 5. Written Test Score

Unit 12: Capacitor Motors

____ 1. Draw connecting wiring for a CS motor with a current relay.
____ 2. Draw connecting wiring for a PSC motor.
____ 3. Draw connecting wiring for a CSR motor.
____ 4. Wire a CS compressor with a current relay.
____ 5. Wire a PSC motor.
____ 6. Wire a CSR compressor motor.
____ 7. Disassemble, inspect, clean, reassemble, and check operation of a PSC fan motor.
____ 8. Use a hermetic analyzer to start, reverse, and check operation of a PSC compressor motor.
____ 9. Install a hard start kit.
____ 10. ____________________
____ 11. Written Test Score

Unit 13: Three-Phase Motors

____ 1. Draw connecting wiring for wye wound and delta wound dual-voltage motors.
____ 2. Wire a dual-voltage, three-phase motor, reverse rotation, and check operation.
____ 3. ____________________
____ 4. Written Test Score

Unit 14: Troubleshooting ACR System Electrical Circuits

____ 1. Identify components on ACR system electrical diagrams.
____ 2. Identify ACR system operation from ACR system electrical diagrams.
____ 3. Select test instruments or procedures for specific ACR system troubleshooting.
____ 4. Solve ACR electrical troubleshooting problems.
____ 5. Troubleshoot series electrical circuits.
____ 6. Troubleshoot parallel electrical circuits.
____ 7. Troubleshoot series-parallel electrical circuits.
____ 8. ____________________
____ 9. Written Test Score

Unit 15: ACR System Wiring Diagrams

____ 1. Draw wiring diagrams for a refrigerator with a coil-type current relay.
____ 2. Draw wiring diagrams for a refrigerator with a solid-state start relay.
____ 3. Draw wiring diagrams for a window air conditioner.
____ 4. Draw wiring diagrams for a standard upflow gas furnace.
____ 5. Draw wiring diagrams for a standard downflow gas furnace.
____ 6. Draw wiring diagrams for a multiposition gas furnace with an integrated control board.
____ 7. Draw wiring diagrams for a condensing unit.
____ 8. Draw wiring diagrams for an electric furnace.
____ 9. Draw wiring diagrams for a condensing unit and an air handler.
____ 10. Draw a ladder schematic for a domestic refrigerator.
____ 11. Observe a domestic refrigerator and draw a ladder schematic of its electrical circuits.
____ 12. Observe a window air conditioner and draw a ladder schematic of its electrical circuits.
____ 13. Observe a heating/cooling system with 24V controls and draw a ladder schematic of its electrical circuits.
____ 14. ____________________
____ 15. Written Test Score

Comments:

____
____
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Evaluator: ______________________________ Date: ______________________

Permission to duplicate this profile is granted.

ACR Electrical Systems

Instructional/Task Analysis

Related Information:
What the Student Should Know

Application:
What the Student Should be Able to Do

Unit 1: Fundamentals of Electricity

1. Terms and definitions
2. Electricity and its applications
3. Sources and characteristics of electricity
4. The electron theory
5. The importance of electrical charges
6. How current is caused to flow in a circuit
7. Insulators, semiconductors, and conductors
8. Direct current
9. Alternating current
10. Electrical loads
11. A basic electrical circuit
12. Basic electrical symbols
13. Three types of circuits
14. Circuit grounding
15. Electrical Measurements
16. Rules governing electricity
17. Three equations for using Ohm's Law
18. Using Ohm's Law to determine unknown values
19. Using Ohm's Law to determine values in a series circuit
20. Using Ohm's Law to determine values in a parallel circuit
21. Using Ohm's Law to determine values in a series-parallel circuit
22. Applications of electronics in ACR control systems
23. Convert electrical measurements to basic units. (Assignment Sheet 1)
24. Use Ohm's Law to determine unknown values in resistive circuits. (Assignment Sheet 2)

Related Information:
What the Student Should Know

Application:
What the Student Should be Able to Do

Unit 2: Tools, Materials, and Test Instruments

1. Terms and definitions
2. Tools
3. Electrical wiring
4. Connecting electrical wires
5. Guidelines for splicing wires
6. Connecting wires to terminals
7. Test instrument characteristics
8. Reading test instruments
9. Using voltmeters and voltage testers
10. Using ohmmeters
11. Using ohmmeters to check motors
12. Checking a hermetic motor with an ohmmeter
13. Using ammeters
14. Useful test accessories
15. Effects of current on the human body
16. How to avoid electrical accidents
17. Rescue procedures for electrical accidents
18. Read a voltmeter. (Assignment Sheet 1)
19. Read an ammeter. (Assignment Sheet 2)
20. Read an ohmmeter. (Assignment Sheet 3)
21. Identify start, run, and common terminals and draw the windings of a single-phase motor. (Assignment Sheet 4)
22. Solder terminals onto wires. (Job Sheet 1)
23. Splice wires using wire nuts. (Job Sheet 2)
24. Use digital and analog voltmeters to check power sources. (Job Sheet 3)
25. Use an ohmmeter to check continuity of fuses. (Job Sheet 4)
26. Use an ohmmeter to determine the resistance of resistors. (Job Sheet 5)
27. Use an ohmmeter to identify terminals and electrical condition of a hermetic compressor. (Job Sheet 6)
28. Use an ammeter to read start and run amperage of a motor. (Job Sheet 7)

Unit 3: Electrical Power

1. Terms and definitions
2. Characteristics of electrical power
3. Transformers
4. Power Distribution
5. Types of power supplies
6. Delivery systems
7. Problems with power delivery
8. Power consumption
9. Watt's Law
10. Measuring power consumption
11. Reading a watt-hour meter
12. Use Watt's Law to determine power. (Assignment Sheet 1)
13. Read an electric watt-hour meter. (Assignment Sheet 2)
14. Use a wattmeter and an ammeter to determine watts. (Job Sheet 3)

Instructional/Task Analysis

Related Information:
What the Student Should Know

Application:
What the Student Should be Able to Do

Unit 4: Circuits, Symbols, and Diagrams

1. Terms and definitions
2. Electronic circuits
3. Integrated circuits
4. The language of electricity
5. Sources and applications of wiring diagrams
6. Pictorial wiring diagrams
7. Schematic wiring diagrams
8. Electronic wiring diagrams
9. Drawing a pictorial diagram
10. Building a ladder schematic diagram
11. Using symbols
12. Draw pictorials, fabricate working models, and draw ladder schematics for basic series and parallel circuits. (Job Sheet 1)
13. Draw pictorials, fabricate working models, and draw ladder schematics for series-parallel circuits. (Job Sheet 2)
14. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with varied loads and switching. (Job Sheet 3)

Unit 5: Protection Devices

1. Terms and definitions
2. Controls and their applications
3. Types of controls
4. Control systems
5. Switch configurations and symbols
6. Switch symbols
7. Applications of shunt circuits
8. Electronic switching
9. Protection devices
10. Overcurrent protection devices
11. Pressure-actuated protection devices
12. Motor protection devices
13. Bimetal protection devices
14. Protecting electronic circuits
15. Draw pictorials, fabricate working models, and draw ladder schematics for shunt circuits with one SPST switch. (Job Sheet 1)
16. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with 3-way switches. (Job Sheet 2)
17. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with 3-way and 4-way switches. (Job Sheet 3)
18. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with safety switches. (Job Sheet 4)
19. Draw a pictorial, fabricate a working model, and draw a ladder schematic of a basic refrigeration circuit. (Job Sheet 5)

Related Information:
What the Student Should Know

Application:
What the Student Should be Able to Do

Unit 6: Transformers and Relays

1. Terms and definitions
2. How a transformer works
3. Control transformer specifications
4. Providing DC power
5. Relay components and their uses
6. Using relay symbols in electrical drawings
7. Control relays and contactors
8. Control relays and contacts and their switching arrangements
9. Types of motor starting relays and their uses
10. Starting current relay operations
11. Motor starting current relay specifications
12. Starting voltage relay (potential relay) operations
13. Potential relay specifications
14. Time-delay relays
15. Electronic controls for timed functions
16. Identify selected relays. (Assignment Sheet 1)
17. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with basic relays. (Job Sheet 1)
18. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with dual relays. (Job Sheet 2)
19. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with special applications. (Job Sheet 3)
20. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with multiple relays. (Job Sheet 4)
21. Check current relays with an ohmmeter. (Job Sheet 5)
22. Check potential relays with an ohmmeter. (Job Sheet 6)
23. Check current relays with an ohmmeter and a voltmeter. (Job Sheet 7)
24. Check a potential relay with an ohmmeter and a voltmeter. (Job Sheet 8)
25. Install a solid-state, time-delay relay. (Job Sheet 9)

Unit 7: Thermostats

1. Terms and definitions
2. Thermostat types and their applications
3. Temperature sensors
4. Electrical contacts
5. Major components of a heating/cooling thermostat
6. Heating thermostat anticipation
7. Cooling thermostat anticipation
8. Installing heating/cooling thermostats
9. Multistage thermostats
10. Subbase applications
11. Internal thermostat switching

16. Install a wall thermostat and determine heat anticipation. (Job Sheet 1)
17. Replace a thermostat with an electronic programmable thermostat. (Job Sheet 2)
18. Program a programmable thermostat. (Job Sheet 3)

Instructional/Task Analysis

Related Information:
What the Student Should Know

Application:
What the Student Should be Able to Do

Unit 7: Thermostats (Continued)

12. Programmable thermostat applications
13. Electronic thermostat applications
14. Benefits of solid-state thermostats
15. Special applications of line voltage thermostats

Unit 8: Introduction to Electric Motors

1. Terms and definitions
2. Electric motor applications
3. Types of electric motors
4. Basic DC motor operation
5. Basic AC motor operation
6. Single-phase AC motor starting
7. Electronically commutated motors
8. AC electric motor parts and their functions
9. Types of motor construction
10. Motor mounts and typical applications
11. Motor data plates
12. Pulleys and belts
13. Pulley selection
14. Sizing and selecting V-belts
15. Troubleshooting electric motors

16. Use a pulley selection chart. (Assignment Sheet 1)
17. Solve electric motor problems. (Assignment Sheet 2)
18. Replace a missing V-belt, adjust tension, and check motor operation. (Job Sheet 1)

Unit 9: Shaded-Pole Motors

1. Terms and definitions
2. Characteristics and applications of shaded-pole motors
3. Shaded-pole motor construction
4. Controlling shaded-pole motor speed
5. Shaded-pole motor rotation
6. Troubleshooting shaded-pole motors
7. The power factor for watt/amp amp/watt conversion

8. Wire a shaded-pole motor to a voltage supply. (Job Sheet 1)
9. Disassemble, inspect, clean, reassemble, and check operation of a shaded-pole motor. (Job Sheet 2)

Related Information:
What the Student Should Know

Application:
What the Student Should be Able to Do

Unit 10: Split-Phase Motors

1. Terms and definitions
2. Characteristics and applications of split-phase motors
3. Split-phase motor construction
4. Split-phase motor starting mechanisms
5. Wiring connections for split-phase motors
6. Troubleshooting split-phase motor
7. Wire a split-phase motor to an AC power source. (Job Sheet 1)
8. Wire a dual-voltage, split-phase motor for 120 VAC. (Job Sheet 2)
9. Wire a dual-voltage, split-phase motor for 208/240 VAC. (Job Sheet 3)
10. Disassemble, inspect, clean, reassemble, and check operation of a split-phase motor. (Job Sheet 4)

Unit 11: Capacitors

1. Terms and definitions
2. Capacitors in ACR circuit applications
3. Effects of inductive loads on current/voltage relationships
4. Capacitor construction and operation
5. Types of capacitors
6. Guidelines for capacitor replacement
7. Grouping capacitors
8. Calculate ratings of grouped capacitors. (Assignment Sheet 1)
9. Check capacitors with an analog ohmmeter. (Job Sheet 1)
10. Check capacitors with a capacitor analyzer. (Job Sheet 2)

Unit 12: Capacitor Motors

1. Terms and definitions
2. Effects of capacitors on motors
3. Applications of capacitors to motors
4. CS motor characteristics and applications
5. PSC motor characteristics and applications
6. CSR motor characteristics and applications
7. Troubleshooting capacitor motors
8. Troubleshooting capacitor motor start components
9. Draw connecting wiring for a CS motor with a current relay. (Assignment Sheet 1)
10. Draw connecting wiring for a PSC motor. (Assignment Sheet 2)
11. Draw connecting wiring for a CSR motor. (Assignment Sheet 3)
12. Wire a CS compressor with a current relay. (Job Sheet 1)
13. Wire a PSC motor. (Job Sheet 2)
14. Wire a CSR compressor motor. (Job Sheet 3)
15. Disassemble, inspect, clean, reassemble, and check operation of a PSC fan motor. (Job Sheet 4)
16. Use a hermetic analyzer to start, reverse, and check operation of a PSC compressor motor. (Job Sheet 5)
17. Install a hard start kit. (Job Sheet 6)

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should be Able to Do

Unit 13: Three-Phase Motors

1. Terms and definitions
2. Characteristics and applications of three-phase motors
3. Three-phase motor construction
4. Wiring connections for three-phase motors
5. Troubleshooting three-phase motors

6. Draw connecting wiring for wye wound and delta wound dual-voltage motors. (Assignment Sheet 1)
7. Wire a dual-voltage, three-phase motor, reverse rotation, and check operation. (Job Sheet 1)

Unit 14: Troubleshooting ACR System Electrical Circuits

1. Terms and definitions
2. Guidelines for troubleshooting ACR system electrical circuits
3. Identifying circuit components and their operations
4. Guidelines for test meter selection
5. Using a voltmeter
6. Applying the hopscotch method for troubleshooting
7. Using an ammeter
8. Using an ohmmeter
9. Checking for shorts and grounds
10. Using jumpers
11. Troubleshooting techniques

12. Identify components on ACR system electrical diagrams. (Assignment Sheet 1)
13. Identify ACR system operation from ACR system electrical diagrams. (Assignment Sheet 2)
14. Select test instruments or procedures for specific ACR system troubleshooting. (Assignment Sheet 3)
15. Solve ACR electrical troubleshooting problems. (Assignment Sheet 4)
16. Troubleshoot series electrical circuits. (Job Sheet 1)
17. Troubleshoot parallel electrical circuits. (Job Sheet 2)
18. Troubleshoot series-parallel electrical circuits. (Job Sheet 3)

Unit 15: ACR System Wiring Diagrams

1. Terms and definitions
2. Guidelines for drawing system diagrams
3. ACR components and their schematic symbols
4. ACR system switches and their schematic symbols
5. Solid-state components and their schematic symbols

7. Draw wiring diagrams for a refrigerator with a coil-type current relay. (Assignment Sheet 1)
8. Draw wiring diagrams for a refrigerator with a solid-state start relay. (Assignment Sheet 2)
9. Draw wiring diagrams for a window air conditioner. (Assignment Sheet 3)
10. Draw wiring diagrams for a standard upflow gas furnace. (Assignment Sheet 4)

Unit 15: ACR System Wiring Diagrams (Continued)

Related Information: What the Student Should Know	Application: What the Student Should be Able to Do
6. The procedure for drawing typical ACR system wiring diagrams	11. Draw wiring diagrams for a standard downflow gas furnace. (Assignment Sheet 5)
	12. Draw wiring diagrams for a multiposition gas furnace with an integrated control board. (Assignment Sheet 6)
	13. Draw wiring diagrams for a condensing unit. (Assignment Sheet 7)
	14. Draw wiring diagrams for an electric furnace. (Assignment Sheet 8)
	15. Draw wiring diagrams for a condensing unit and an air handler. (Assignment Sheet 9)
	16. Draw a ladder schematic for a domestic refrigerator. (Assignment Sheet 10)
	17. Observe a domestic refrigerator and draw a ladder schematic of its electrical circuits. (Job Sheet 1)
	18. Observe a window air conditioner and draw a ladder schematic of its electrical circuits. (Job Sheet 2)
	19. Observe a heating/cooling system with 24V controls and draw a ladder schematic of its electrical circuits. (Job Sheet 3)

SCANS Foundation Skills for *ACR Electrical Systems*

Task	Skill Group or Competency	Subskill or Competency	Description
Unit 1: Fundamentals of Electricity			
Convert electrical measurements to basic units. (AS 1)	Basic skills	Mathematics	Converts electrical measurements to proper metric notations.
Use Ohm's Law to determine unknown values in resistive circuits. (AS 2)	Basic skills	Science	Uses a scientific formula to determine electrical power in a circuit.
Unit 2: Tools, Materials, and Test Instruments			
Read a voltmeter. (AS 1)	Technology	Application	Demonstrates the ability to read a test instrument.
Read an ammeter. (AS 2)			Demonstrates the ability to read a test instrument.
Read an ohmmeter. (AS 3)			Demonstrates the ability to read a test instrument.
Identify start, run, and common terminals and draw the windings of a single- phase motor. (AS 4)	Basic skills	Science	Applies knowledge learned through training to identify component functions.
Solder terminals onto wires. (JS 1)	Technology	Application	Demonstrates proper procedure for completing a service routine.
Splice wires using wire nuts. (JS 2)	Technology	Application	Demonstrates proper procedure for completing a service routine.
Use digital and analog voltmeters to check power sources. (JS 3)	Technology	Application	Demonstrates the ability to apply and read a test instrument.
Use an ohmmeter to determine the resistance of resistors. (JS 4)	Technology	Application	Demonstrates the ability to apply and read a test instrument.
Use an ohmmeter to check continuity of fuses. (JS 5)	Technology	Application	Demonstrates the ability to apply and read a test instrument.
Use an ohmmeter to identify terminals and electrical conditions of a hermetic compressor. (JS 6)	Technology	Application	Demonstrates the ability to apply and read a test instrument.
Use an ammeter to read start and run amperage of a motor. (JS 7)	Technology	Application	Demonstrates the ability to apply and read a test instrument.
Unit 3: Electrical Power			
Use Watt's Law to determine power. (AS 1)	Basic skills	Science	Applies a scientific formula to determine power.
Read an electric watt-hour meter. (AS 2)	Technology	Application	Demonstrates the ability to read an electric test instrument.
Use a wattmeter and an ammeter to determine watts. (AS 3)	Technology	Application	Demonstrates the ability to apply and read test instruments.

Task	Skill Group or Competency	Subskill or Competency	Description
Unit 4: Circuits, Symbols, and Diagrams			
Draw pictorials, fabricate working models, and draw ladder schematics for basic series and parallel circuits. (JS 1)	Basic skills	Science	Applies knowledge and reasoning skills learned through study to build series circuits and depict the circuits in schematic forms.
Draw pictorials, fabricate working models, and draw ladder schematics for series- parallel circuits. (JS 2)	Basic skills	Science	Applies knowledge and reasoning skills learned through study to build series-parallel circuits and depict the circuits in schematic forms.
Draw pictorials, fabricate working models, and draw ladder schematics for circuits with varied loads and switching. (JS 3)	Basic skills	Science	Applies knowledge and reasoning skills learned through study to build circuits with varied loads and switching and depict the circuits in schematic forms.
Unit 5: Protection Devices			
Draw pictorials, fabricate working models, and draw ladder schematics for shunt circuits with one SPST switch. (JS 1)	Basic skills	Science	Applies knowledge and reasoning skills learned through study to build circuits with an SPST switch and depict the circuits in schematic forms.
Draw pictorials, fabricate working models, and draw ladder schematics for circuits with 3-way switches. (JS 2)	Basic skills	Science	Applies knowledge and reasoning skills learned through study to build circuits with 3-way switches and depict the circuits in schematic forms.
Draw pictorials, fabricate working models, and draw ladder schematics for circuits with 3-way and 4-way switches. (JS 3)	Basic skills	Science	Applies knowledge and reasoning skills learned through study to build circuits with 3-way and 4-way switches and depict the circuits in schematic forms.
Draw pictorials, fabricate working models, and draw ladder schematics for circuits with safety switches. (JS 4)	Basic skills	Science	Applies knowledge and reasoning skills learned through study to build circuits with safety switches and depict the circuits in schematic forms.
Draw pictorials, fabricate working models, and draw a ladder schematic for a basic refrigeration circuit. (JS 5)	Basic skills	Science	Applies knowledge and reasoning skills learned through study to build a circuit for a basic refrigeration circuit and depict the circuit in schematic form.
Unit 6: Transformers and Relays			
Identify selected relays. (AS 1)	Basic skills	Science	Applies knowledge learned through training to identify selected components.
Draw pictorials, fabricate working models, and draw ladder schematics for circuits with basic relays. (JS 1)	Basic skills	Science	Applies knowledge and reasoning skills learned through training to build circuits with basic relays and depict the circuits in schematic forms.

SCANS Foundation Skills

Unit 6: Transformers and Relays (Continued)

Task	Skill Group or Competency	Subskill or Competency	Description
Draw pictorials, fabricate working models, and draw ladder schematics for circuits with dual relays. (JS 2)	Basic skills	Science	Applies knowledge and reasoning skills learned through training to build circuits with dual relays and depict the circuits in schematic forms.
Draw pictorials, fabricate working models, and draw ladder schematics for circuits with special applications. (JS 3)	Basic skills	Science	Applies knowledge and reasoning skills learned through training to build circuits with special applications and depict the circuits in schematic forms.
Draw pictorials, fabricate working models, and draw ladder schematics for circuits with multiple relays. (JS 4)	Basic skills	Science	Applies knowledge and reasoning skills learned through training to build circuits with multiple relays and depict the circuits in schematic forms.
Check current relays with an ohmmeter. (JS 5)	Technology	Application	Demonstrates the ability to apply and read a test instrument.
Check potential relays with an ohmmeter. (JS 6)	Technology	Application	Demonstrates the ability to apply and read a test instrument.
Check current relays with an ohmmeter and a voltmeter. (JS 7)	Technology	Application	Demonstrates the ability to apply and read a test instrument.
Check a potential relay with an ohmmeter and a voltmeter. (JS 8)	Technology	Application	Demonstrates the ability to apply and read multiple test instruments.
Install a solid-state, time-delay relay. (JS 9)	Technology Basic skills	Application Reading	Demonstrates the ability to install a solid-state device to written specifications.

Unit 7: Thermostats

Task	Skill Group or Competency	Subskill or Competency	Description
Install a wall thermostat and determine heat anticipation. (JS 1)	Technology Basic skills	Application Reading	Demonstrates the ability to install a thermostat to written specifications.
Replace a thermostat with an electronic programmable thermostat. (JS 2)	Technology Basic skills	Application Reading	Demonstrates the ability to replace an analog thermostat with a digital thermostat according to written specifications.
Program a programmable thermostat. (JS 3)	Technology Basic skills	Application Reading	Demonstrates the ability to custom program thermostat setbacks to reflect customer needs.

Unit 8: Introduction to Electric Motors

Task	Skill Group or Competency	Subskill or Competency	Description
Use a pulley selection chart. (AS 1)	Technology Basic skills	Application Reading	Demonstrates the ability to select equipment from a supplier's catalog.
Solve electric motor problems. (AS 2)	Technology Basic skills	Application Reading	Demonstrates the ability to read and follow instructions for equipment installation.
Replace a missing V-belt, adjust tension, and check motor operation. (JS 1)	Technology Basic skills	Application Science & Reading	Demonstrates the ability to apply scientific formulas for V-belt adjustment and to apply test instruments for a motor check.

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Unit 9: Shaded-Pole Motors

Task	Skill Group or Competency	Subskill or Competency	Description
Wire a shaded-pole motor to a voltage supply. (JS 1)	Technology	Application	Demonstrates the ability to identify motor terminals and connect them to a specified power supply.
Disassemble, inspect, clean, reassemble, and check operation of a shaded-pole motor. (JS 2)	Technology	Application	Demonstrates the ability to inspect motor components and evaluate their condition based on visual evidence of wear.

Unit 10: Split-Phase Motors

Task	Skill Group or Competency	Subskill or Competency	Description
Wire a split-phase motor to an AC power source. (JS 1)	Technology	Application	Demonstrates the ability to identify motor terminals and connect them to a specified power supply.
Wire a dual-voltage, split-phase motor for 120 VAC. (JS 2)	Technology	Application	Demonstrates the ability to identify motor terminals and connect them to a 120 V power supply.
Wire a dual-voltage, split-phase motor for 208/240 VAC. (JS 3)	Technology	Application	Demonstrates the ability to identify motor terminals and connect them to a 208/240 V power supply.
Disassemble, inspect, clean, reassemble, and check operation of a split-phase motor. (JS 4)	Technology	Application	Demonstrates the ability to inspect motor components and evaluate their condition based on visual evidence of wear.

Unit 11: Capacitors

Task	Skill Group or Competency	Subskill or Competency	Description
Calculate ratings of grouped capacitors. (AS 1)	Basic skills	Mathematic	Demonstrates the ability to apply mathematical rules to a component application.
Check capacitors with an analog ohmmeter. (JS 1)	Technology	Application	Demonstrates the ability to apply and read a test instrument for a service application.
Check capacitors with a capacitor analyzer. (JS 2)	Technology	Application	Demonstrates the ability to apply and read a test instrument for a service application.

Unit 12: Capacitor Motors

Task	Skill Group or Competency	Subskill or Competency	Description
Draw connecting wiring for a CS motor with a current relay. (AS 1)	Technology	Application	Demonstrates the ability to wire a relay into a motor circuit.
Draw connecting wiring for a PSC motor. (AS 2)	Technology	Application	Demonstrates the ability to identify motor terminals and indicate power source connections.
Draw connecting wiring for a CSR motor. (AS 3)	Technology	Application	Demonstrates the ability to identify motor terminals and indicate power source connections.
Wire a CS compressor with a current relay. (JS 1)	Technology	Application	Demonstrates the ability to wire a relay into a CS compressor circuit.
Wire a PSC motor. (JS 2)	Technology	Application	Demonstrates the ability to identify wiring and power source connections for a PSC motor.

SCANS Foundation Skills

Task	Skill Group or Competency	Subskill or Competency	Description
Unit 12: Capacitor Motors (Continued)			
Wire a CSR compressor motor. (JS 3)	Technology	Application	Demonstrates the ability to identify wiring and power source connections for a CSR compressor motor.
Disassemble, inspect, clean, reassemble, and check operation of a PSC fan motor. (JS 4)	Technology	Application	Demonstrates the ability to inspect motor components and evaluate their condition based on visual evidence of wear.
Use a hermetic analyzer to start, reverse, and check operation of a PSC compressor motor. (JS 5)	Technology	Application	Demonstrates the ability to apply a test instrument for evaluating motor performance.
Install a hard start kit. (JS 6)	Technology Basic skills	Application Reading	Demonstrates the ability to install a motor starting device to written specifications.
Unit 13: Three-Phase Motors			
Draw connecting wiring for wye wound and delta wound dual-voltage motors. (AS 1)	Technology	Application	Demonstrates the ability to identify terminals and draw connecting wiring for dual-voltage motors.
Wire a dual-voltage, three-phase motor, reverse rotation, and check operation. (JS 1)	Technology	Application	Demonstrates the ability to wire a three- phase motor to a power source, reverse its rotation and check its operation.
Unit 14: Troubleshooting ACR System Electrical Circuits			
Identify components on ACR system electrical diagrams. (AS 1)	Basic skills	Science	Applies knowledge learned through training to identify components in a diagram.
Identify ACR system operation from ACR system electrical diagrams. (AS 2)	Basic skills	Science	Applies knowledge learned through training to identify system operations in a diagram.
Select test instruments or procedures for specific ACR system troubleshooting. (AS 3)	Basic skills	Science	Applies knowledge learned through training to select test instruments and procedures for troubleshooting ACR systems.
Solve ACR electrical trouble-shooting problems. (AS 4)	Thinking skills	Problem solving	Recognizes a problem and implements a solution.
Troubleshoot series electrical circuits. (JS 1)	Technology	Application	Demonstrates the ability to use a schematic to troubleshoot series electrical circuits.
Troubleshoot parallel electrical circuits. (JS 2)	Technology	Application	Demonstrates the ability to use a schematic to troubleshoot parallel electrical circuits.
Troubleshoot series-parallel electrical circuits. (JS 3)	Technology	Application	Demonstrates the ability to use a schematic to troubleshoot series-parallel electrical circuits.

Unit 15: ACR System Wiring Diagrams

Task	Skill Group or Competency	Subskill or Competency	Description
Draw wiring diagrams for a refrigerator with a coil-type current relay. (AS 1)	Basic skills	Science	Applies knowledge learned through training to draw a schematic for a refrigerator with a current relay.
Draw wiring diagrams for a refrigerator with a solid-state start relay. (AS 2)	Basic skills	Science	Applies knowledge learned through training to draw a schematic for a refrigerator with a solid-state start device.
Draw wiring diagrams for a window air conditioner. (AS 3)	Basic skills	Science	Applies knowledge learned through training to draw a schematic for a window air conditioner.
Draw wiring diagrams for a standard upflow gas furnace. (AS 4)	Basic skills	Science	Applies knowledge learned through training to draw schematics for a typical upflow furnace.
Draw wiring diagrams for a standard downflow gas furnace. (AS 5)	Basic skills	Science	Applies knowledge learned through training to draw schematics for a typical downflow furnace.
Draw wiring diagrams for a multiposition gas furnace with an integrated control board. (AS 6)	Basic skills	Science	Applies knowledge learned through training to draw schematics for a typical furnace with an integrated control board.
Draw wiring diagrams for a condensing unit. (AS 7)	Basic skills	Science	Applies knowledge learned through training to draw schematics for a typical condensing unit.
Draw wiring diagrams for an electric furnace. (AS 8)	Basic skills	Science	Applies knowledge learned through training to draw schematics for a typical electric furnace.
Draw wiring diagrams for a condensing unit and an air handler. (AS 9)	Basic skills	Science	Applies knowledge learned through training to draw schematics for a typical condensing unit and an air handler.
Draw a ladder schematic for a domestic refrigerator. (AS 10)	Basic skills	Science	Applies knowledge learned through training to draw a ladder schematic for a typical refrigerator.
Observe a domestic refrigerator and draw a ladder schematic of its electrical circuits. (JS 1)	Technology	Application	Demonstrates the ability to draw a ladder schematic for a specific refrigerator.
Observe a window air conditioner and draw a ladder schematic of its electrical circuits. (JS 2)	Technology	Application	Demonstrates the ability to draw a ladder schematic for a specific air conditioner.
Observe a heating/cooling system with 24V controls and draw a ladder schematic of its electrical circuits. (JS 3)	Technology	Application	Demonstrates the ability to draw a ladder schematic for a specific heating/cooling system with 24V controls.

ACR Electrical Systems

Tools, Equipment, and Materials List

ACR Technician's Hand Tools

See VICA Student Tool Kit, next page
Jumper wires
Bleed resistors
Scratch awl
Screw starter
Small level
Open end wrenches
Soldering Iron
Rawhide or soft-faced hammer

Test Instruments

Voltmeter, analog & digital
Ohmmeter, analog & digital
Ammeter, analog & digital
Multimeter, analog & digital
Wattmeter
Amp multiplier or ten-wrap coil
Capacitor analyzer
Hermetic motor analyzer

Working Model Simulators

Fabrication/wiring boards
Troubleshooting trainers

Components

Current relays
Potential relays
Solid-state time-delay relay
Thermostats w/heat anticipation
Thermostat subbases (for demonstration)
Electronic programmable thermostat
Assorted run and start capacitors

Materials

Four-conductor thermostat cable
Mounting screws or anchors
Conductors of various sizes
Fasteners as required
Shop rags
Sand cloth
Extra-fine sandpaper
Terminals
Electrical tape
Wire nuts
Resin-core solder

Pulleys, belts, and special items

Standard pulley (for demonstration)
Step pulley (for demonstration)
Adjustable pulley (for demonstration)
Replacement V-belt
Straight edge
Tension gauge
Belt dressing

Motors and special items

Assorted sizes of shaded-pole, split-phase, capacitor, and three-phase motors
Motor test cord
Bench vise
Compressed air
Motor cleaning fluid
Electric motor bearing oil
Hard start components

ACR Electrical Systems

Suggested Student Tool Kit

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Toolbox with lock and name tag
Rule (12")
Measuring tape (12')
Electrical tape
Electrical wire nuts
Electrical wire terminals
VOM/analog-digital meter
Flat-tip screwdrivers (assortment of four sizes)
Phillips-head screwdrivers (assortment of four sizes)
Nutdrivers (set of seven)
Electrician's knife
Longnose pliers (6")
Diagonal pliers
Wirecutters (6")
Slipjoint pliers (6")
Adjustable wrench (8" or 10")
Locking pliers (6")
Arc-joint pliers (8" or 10")
Ball peen hammer
Soldering iron
Crimping tool
Drive socket set with extensions (1/4" and 3/8")
Hacksaw/extra blades
Pocket thermometer
Mercury thermometer
Safety glasses
Torch striker
Gauge manifold set with quick connect hose
Flaring kit
Swaging kit
Clamp-on ampmeter
Allen wrench set

The VICA Student Tool Kit contains some items not specifically needed for *ACR Electrical Systems*; however, the complete kit is essential for students working with other MAVCC ACR texts.

ACR Electrical Systems

References

Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.

The Air Conditioning, Heating and Refrigeration News HVACR Source Guide. Troy, MI: Business News Publishing Company, 1995.

Mackert, Howard and Russell Heiserman. *Automotive Electronics.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1988.

Smrecker, Eugene and King Calvert. *Major Appliance Repair.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1987.

Wantiez, Gary W. *ACR Electrical Systems and Components.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.

Installation and Maintenance of V-Belt Drives. Chambersburg, PE: T.B. Woods, Inc., 1995.

Fundamentals of Electricity
Unit 1

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan enrichment of exceptional students as well as accommodation of special needs students.
4. Prepare a transparency from TM 1 for use with Objectives 17 through 21.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss and demonstrate the assignment sheets. Review criteria for evaluating these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of written test. Add or modify test items as needed.
13. Give written test.
14. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets added to the unit.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: A SCANS Report for America 2000.* These SCANS skills and competencies have been adapted by MAVCC to help instructors and program planners effectively articulate curriculum.

1. Find an air conditioning service firm owner or a service technician from your area to address the class about the importance of knowing the fundamentals of electricity and how that knowledge converts to skills on the job. **Basic skills, listening.**

2. Invite the same or similar person as referenced in item 1 to talk to the class about some of the tricky problems that a service technician confronts on the job, and how a good electrical problems troubleshooter can solve complex problems that might otherwise consume a great deal of time and create customer dissatisfaction. **Thinking skills, seeing things in the mind's eye.**

3. Group students into teams and then assign each team to visit a local company or individual's shop to learn about specific local problems that may be related to local utility service, weather conditions, or other situations that localize troubleshooting, and specifically electrical troubleshooting. Have students prepare a short report about problems confronted and materials or replacement parts required to correct problems. Have students present their findings to the class in the form of a team report. **Interpersonal skills, teamwork.**

Resources Used in Developing This Unit

1. Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.

2. *The Air Conditioning, Heating and Refrigeration News HVACIR Source Guide.* Troy, MI: Business News Publishing Company, 1995.

3. Mackert, Howard and Russell Heiserman. *Automotive Electronics.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1988.

4. Smrecker, Eugene and King Calvert. *Major Appliance Repair.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1987.

5. Wantiez, Gary W. *ACR Electrical Components and Systems.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.

Suggested Activities

Suggested Supplemental Resources

In their general training series, Carrier Training Services has several modules dedicated to the electrical elements of ACR training. The Modules by name and number include:

Module 1, Introduction to Electricity
Module 2, Electrical Components and Their Symbols
Module 3, Wiring Diagrams
Module 4, Wiring Diagram Exercises
Module 5, Electric Meters and Their Uses
Module 6, Alternating Current Fundamentals
Module 7, Motor Fundamentals and Motor Protection
Module 8, Electronic Devices and Circuits
Module 9, Electrical Troubleshooting

The well executed series is enhanced with full color graphics and includes VHS videos, audio cassettes, and student workbooks. Quantity discounts are available for vo-tech schools and other training institutions. For a catalog of these and other materials from Carrier Training Services, write to:

Literature Services, Bldg. TR-8
P. O. Box 4808
Syracuse, NY 13221

The nature of electricity and rules governing electricity are two major subjects in Honeywell's *Fundamentals of Residential Controls.* This inexpensive text is one of Honeywell's programmed instruction books built around a step-by-step, question-answer format. Other topics in the well-illustrated text include inductive and capacitive circuits, principles of motor operation, power, transformer principles, relay principles, analyzing control circuits . The Honeywell product number for this impressive 250-page workbook is 71-97083. Check with your Honeywell distributor or call Honeywell at 1-800/345-6770, ext. 2040.

Suggested Activities

Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Option A

4—Can perform job with no additional training.
3—Moderately skilled—Has performed job during training program; limited additional training may be required.
2—Limited skill—Has performed job during training program; additional training is required to develop skill.
1—Unskilled—Is familiar with process but is unable to perform job.

Option B

Yes—Can perform job with no additional training.
No—Is unable to perform job.

Fundamentals of Electricity
Unit I

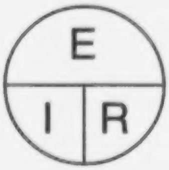
Answers to Assignment Sheets

Assignment Sheet 1

A. .0000015A
B. 1,010,000W
C. .030V
D. 3,000,000Ω
E. 10A

Assignment Sheet 2

A.



B. 30A
C. 3Ω
D. 240V
E. (1) 30Ω
  (2) .8 A
  (3) 16V
F. (1) 2.22Ω
  (2) 10.8 1A
  (3) 24V
G. (1) 13.33Ω
  (2) 1.8A
  (3) 18V
  (4) 6V

Fundamentals of Electricity
Unit 1

Answers to Written Test

1. a. 4
   b. 8
   c. 2
   d. 9
   e. 6
   f. 1
   g. 7
   h. 3
   i. 5

2. a. mechanical action
   b. lightning
   c. power
   d. transformer
   e. parallel
   f. controlled

3. a. 4
   b. 2
   c. 5
   d. 3
   e. 6
   f. 1

4. a, d, e, f, g

5. a. (2)
   b. (1)
   c. (2)

6. a. battery
   b. negative, positive (order may vary)
   c. negative, negative
   d. positive, negative
   e. potential difference
   f. potential difference

7. a. insulators
   b. semiconductors
   c. conductors

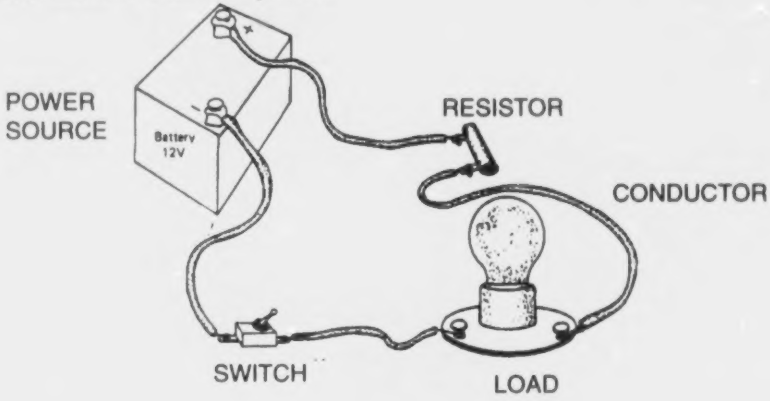
8. b, c, e, g

Answers to Written Test

9. a. generator
   b. motion
   c. induced
   d. magnetic field
   e. parallel, perpendicular
   f. rises, drops, rises
   g. one cycle
   h. cycles, hertz
   i. power loss

10. a. (1)
    b. (2)

11. Note: Circuit configuration may vary, but must contain minimum items illustrated; resistor or load alone is also acceptable.



12. a. AC power source
    b. DC power source
    c. Conductor with connection
    d. General load
    e. Resistor
    f. Light
    g. Single pole single throw

13. a. Series-parallel circuit
    b. Series circuit
    c. Parallel circuit

14. a, b, c, d, e

Answers to Written Test

15. a. characteristics
    b. duplication
    c. comparison
    d. basic requirement
    e. metric
    f. basic units

16. a. EMF, voltage, volts (V)
    b. Intensity of current, amperage, amps (A)
    c. Resistance, ohms (Ω)

17. a. $E = I \times R$
    b. $I = E/R$
    c. $R = E/I$

18. a. E, multiply I x R
    b. I, divide E by R
    c. R, divide E by I

19. a. (1)
    b. (2)
    c. (1)

20. a. (2)
    b. (3)
    c. (2)
    d. (1)

21. a. (2)
    b. (1)
    c. (2)

22. a. solid-state
    b. smaller
    c. thermostats
    d. theory, test

Fundamentals of Electricity
Unit I

Written Test

Name ______________________________ Date __________ Score ________

1. Match each term on the right with its correct definition.

_____ a. Alternating current, an electrical current that reverses its direction of flow at regular intervals

_____ b. A path for electrical current that completes a

_____ c. Direct current, a current that travels in one direction only

_____ d. That branch of science that deals with the phenomena of electric energy and its applications

_____ e. In electrical circuitry, the application of small, solid-state components capable of performing a multitude of functions at a high rate of speed

_____ f. The number of times something happens in a given period of time as in the cycling of alternating current

_____ g. The use of superscript numbers such as 10^6 to indicate ten to the sixth power or the use of subscript numbers to indicate order or other information such as R_1 for resistor 1 or R_T for total resistance

_____ h. An international system of measurement

_____ i. Electrical circuits containing semiconductors

1. Frequency
2. DC
3. Metric
4. AC
5. Solid-state
6. Electronics
7. Mathematical notation
8. Circuit
9. Electricity

Written Test

2. Complete statements about electricity. Write in the word(s) that best completes each of the following statements.

   a. Electricity is a form of energy that can be converted to light, heat, or ______________________ to perform useful work.

   b. Electricity exists in nature as static electricity and as ______________ , but these forms of energy do not perform useful work.

   c. Electricity used for domestic and industrial purposes is generated at ______________________ plants and transmitted by high voltage power lines to towns and cities.

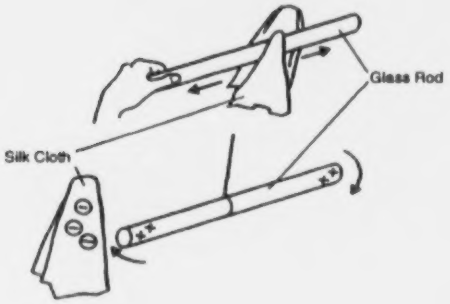
   d. High voltage electricity from a generating plant usually has to go through a __________________________ that steps it down to a lower voltage for home and industry use.

   e. In the average home, electricity is put to work in an arrangement of ____________________ circuits to supply electricity for lighting, heating, air conditioning, and appliance use.

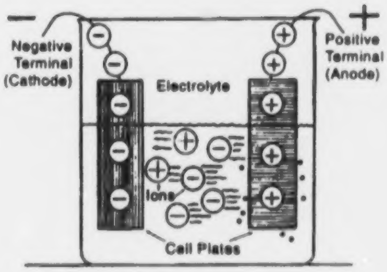
   f. To benefit people, electricity has to be ____________________ , and switches, relays, transformers and other control devices are what make air conditioning and refrigeration equipment useful for modem living.

Written Test

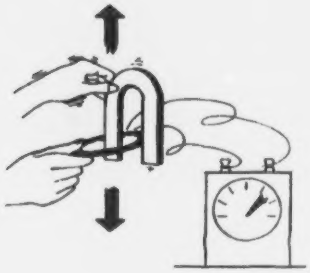
3. Identify sources of electricity and their characteristics. Place the number beside the source in the blank beneath the illustration of the characteristic.


Glass Rod
Silk Cloth

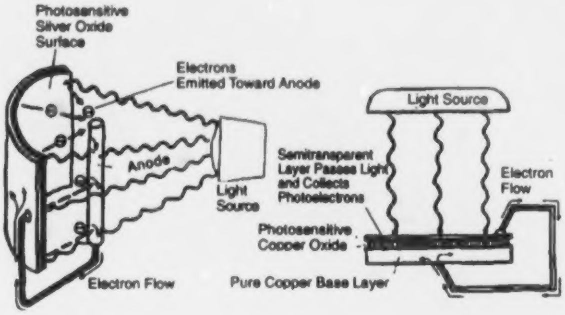
a. __________


−
+
Negative Terminal (Cathode)
Electrolyte
Positive Terminal (Anode)
Ions
Cell Plates

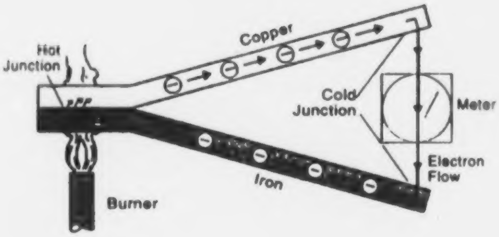
b. __________



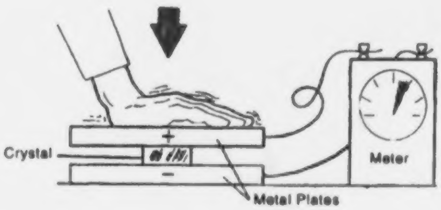
c. __________


Photosensitive Silver Oxide Surface
Electrons Emitted Toward Anode
Anode
Light Source
Electron Flow
Light Source
Semitransparent Layer Passes Light and Collects Photoelectrons
Electron Flow
Photosensitive Copper Oxide
Pure Copper Base Layer

d. __________


Hot Junction
Copper
Cold Junction
Meter
Electron Flow
Iron
Burner

e. __________


Crystal
+
−
Meter
Metal Plates

f. __________

1. Mechanical pressure
2. Chemical reaction
3. Photoelectric surfaces
4. Friction
5. Magnetism
6. Heat

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Written Test

4. Select true statements about the electron theory. Place an "X" beside each true statement.

____ a. Understanding electricity requires basic knowledge of the structure of an atom.

____ b. The nucleus of an atom is made up of neutrons with no electrical charge and protons which have electrical negative charges.

____ c. Electrons with positive charges orbit the nucleus in paths that are called shells.

____ d. Electrons that orbit in inner shells are attracted to the nucleus, but electrons in the outer shell or "valence shell" can be set free.

____ e. When energy is applied to the centrifugal force in an electron, the electron leaves its previous orbit and moves to a higher orbit.

____ f. Since a valence electron has no higher orbit, it will leave the parent atom and move to another atom.

____ g. The negative charge of an electron freed from the valence shell is the basic unit of electricity.

5. Complete statements about the importance of electrical charges. Circle the number in front of the information that best completes each of the following statements.

a. The two most important electrical relationships established by Coulomb are:

(1) unlike charges repel and like charges attract.
(2) like charges repel and unlike charges attract.

b. AC and DC motors are able to perform useful work because of:

(1) the application of the attraction and repulsion principles of electrical charges.
(2) their ability to use transformers effectively.

c. Current flow in a conductor is created because:

(1) positive and negative charges move together in a wire.
(2) positive charges attract negative charges to create electron movement.

Written Test

6. Complete statements about how current is caused to flow in a circuit. Write in the word(s) that best complete each of the following statements.

   a. To create electron or current flow through a conductor requires a source of already energized electrons such as those found in a power source like a ________________________ .

   b. The wire or medium that serves as the conductor must have one end connected to the ________________________ side of the power source and the other end connected to the ________________________ end of the power source.

   c. Negative charges in the power source energize ________________ charges in the conductor and cause those ________________ charges to start moving though the conductor.

   d. The ________________ charges at the other end of the power source attract the electrons from the ________________ side of the power source, and this attraction reinforces electron flow.

   e. The presence of negative charges at one end of a conductor and the absence of negative charges at the other end of the conductor sets up a situation called a ________________________ ____________________ .

   f. A ________________________ ____________________ must be present before electrons will flow in a conductor to create electric current that can be put to work.

7. Complete statements about insulators, semiconductors, and conductors. Write in the word that best completes each of the following statements.

   a. Materials whose atoms have valence electrons strongly attached to the parent atom have high resistance to current flow and make good ____________________ .

   b. Materials whose atoms have valence electrons that are only moderately attached to the parent atom can have their resistance manipulated to be high or low, and these materials make good ____________________ .

   c. Materials that have only one or very few valence electrons have little resistance to current flow and make good ________________ .

Written Test

8. Select true statements about direct current. Place an "X" beside each true statement.

_____ a. The most common source of direct current electricity is common household electricity.

_____ b. Both wet and dry cell batteries operate on the same principle of two dissimilar metals placed in a chemical that reacts upon them.

_____ c. Chemical reaction in a battery creates a potential difference between dissimilar elements and creates a condition for electron flow.

_____ d. Potential difference is also called "resistance" and can be tapped into with wires and directed to an electrical device; this electrical device which used electricity is called a "load."

_____ e. The essential characteristic of direct current is that the strength of the current may rise or fall, but it never becomes negative.

_____ f. When plotted graphically to depict its movement in time, direct current is always nonfluctuating.

_____ g. Direct current is used in many solid-state and electronic control devices.

9. Complete statements about alternating current. Write in the word(s) that best completes each of the following statements.

a. Alternating current is most often produced by a _______________ which uses the principle that a magnetic field can cause current to flow in a conductor.

b. This is accomplished by first placing the conductor in a magnetic field and then putting either the conductor or the magnetic field in _______________ .

c. When current is produced in this manner, we say that current is __________ in the wire.

d. This is done in a simple generator by rotating a coil of wire in a __________ _________________ .

e. As a coil rotates in a magnetic field, it continually changes its direction with respect to the field, which means that it cuts the maximum number of force lines when it is ______________ to the field and cuts no force lines when it is ___________________________ to the field.

Written Test

f. As the coil rotates, voltage continually ____________ to the maximum level, __________ to zero, then __________ to the maximum again, and current reverses itself with each half revolution.

g. Alternating current is identified by its frequency which is determined by the number of revolutions of the coil in one second; each complete revolution of the coil equals __________ ____________ .

h. Most household current in the US reverses itself 120 times per second, which means the voltage rises to 120 volts, then drops back to zero each half cycle, so there are 60 __________ per second or 60 _________ per second.

i. Alternating current can be transmitted from generating sources over long distances without excessive ___________ ____________ and is preferred over direct current.

10. Solve problems about electrical loads. Circle the number in front of the item that best solves each of the following problems.

a. A coworker is talking about an electric motor and referring to it as a resistive load. The problem is:

(1) a motor is an "inductive" load which converts electricity into mechanical motion.
(2) the coworker should have said that the statement applies to very small electric motors only.
(3) the problem is that a motor is a combination of resistive and inductive loads.

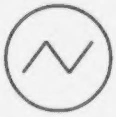
b. A fellow student asked to give an example of a resistive load says that a good example is a relay coil. The problem is:

(1) a relay coil is a combination load.
(2) resistive loads convert electricity into heat or light, not mechanical motion.
(3) a resistive load can only be a resistor.

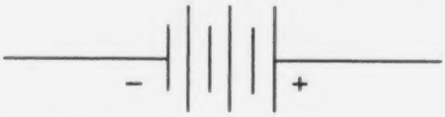
Written Test

11. Sketch a basic electrical circuit. Place the sketch in the following space and be sure to label all components.

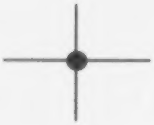
12. Identify the basic electrical symbols. Write the name of the symbol in the blank below its illustration.



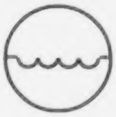
a. __________



b. __________

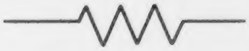


c. __________

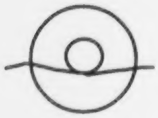


d. __________

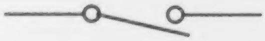
Written Test



e. __________

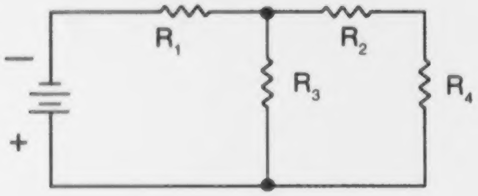


f. __________

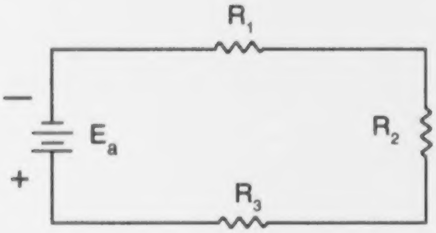


g. __________

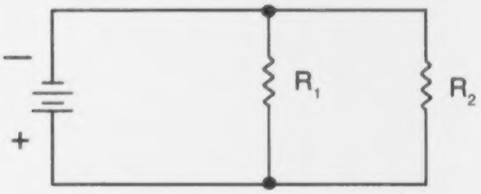
13. Identify the three types of circuits. Write the name of the circuit type in the blank beside its illustration.



a. ______________________



b. ______________________



c. ______________________

Written Test

14. Select true statements about circuit grounding. Place an "X" beside each true statement.

_____ a. A ground in a circuit serves to protect users and technicians against hazardous electrical shock.

_____ b. A ground should not be confused with neutral which may also be designated with the ground symbol.

_____ c. All circuits should be grounded with a ground wire from the power source to a point on the equipment chassis.

_____ d. In cases where a circuit cannot be grounded to the power source, the ground wire should be secured to a cold water pipe or to a grounding rod driven into the ground.

_____ e. Loose grounds create static in radio and television sets and contribute to heat build up in equipment.

_____ f. Most electronic devices will still operate properly without proper grounding, but all electrical devices must have a ground.

15. Complete statements about electrical measurements. Write in the word(s) that best complete each of the following statements.

a. Being able to measure the electrical ____________________ of a circuit is the basis of electrical troubleshooting.

b. Electrical measurements permit ________________ of previous conditions.

c. Electrical measurements permit the _________________ of present electrical conditions with a specified normal condition.

d. Electrical measurements are made with specialized instruments, and knowing how to use test instruments properly is a ________________________ ________________________ for service technicians.

e. In order to use the rules governing electricity, measurements must be expressed in basic units of amps, ohms, and volts, but very large or very small quantities are often expressed using mathematical prefixes from the ___________ system.

f. Metric quantities must be converted to ______ ________ before using them in formulas.

Written Test

16. Define terms and abbreviations used in rules governing electricity. Write in the equations and other information required to complete each of the following definitions.

a. E = ____________ or ____________ measured in ________________ .

b. I = __________ __ __________ or ________________________

measured in __________________ .

c. R = __________________________ measured in ________________ .

17. Write the three equations for using Ohm's Law. Use the appropriate abbreviations to complete each of the following statements.

a. The voltage required to force a given amount of current through a circuit is equal to the current times the resistance:

____.

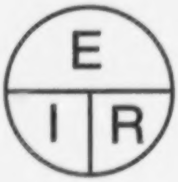
b. The current in a circuit is equal to the voltage divided by the resistance:

____.

c. The resistance of a circuit is equal to the voltage divided by the current:

____.

18. Complete statements about using Ohm's Law to find unknown values. Reference the Ohm's Law graphic below and complete the statements with appropriate symbols.



a. To find voltage, cover ______________ and ______________________.

b. To find amperage, cover ___________ and _______________________.

c. To find resistance, cover ___________ and ______________________.

Written Test

19. Complete statements about using Ohm's Law to determine values in a series circuit. Circle the number in front of the information that best completes each of the following statements.

    a. To determine the total opposition to current flow in a series circuit, resistances may be:

        (1) added.
        (2) multiplied.
        (3) divided.

    b. At all points in a series circuit, current:

        (1) depends on conductor size and applied voltage.
        (2) is the same.
        (3) varies with the size of loads in the circuit.

    c. The formula for voltage drop in a series circuit could best be stated as:

        (1) total voltage drop must equal total applied voltage.
        (2) total voltage drop must equal total circuit resistance.
        (3) total voltage drop must equal amperage divided by resistance.

20. Complete statements about using Ohm's Law to determine values in a parallel circuit. Circle the number in front of the information that best completes each of the following statements.

    a. In parallel circuits:

        (1) voltage across each path varies with total resistance.
        (2) voltage across each path is the same, but the current in each path is different.
        (3) current in each path is the same, but voltage in each path is different.

    b. To find the total current in a parallel circuit, use Ohm's Law to:

        (1) find E and simply double it.
        (2) find R and multiply it by the number of loads in the circuit.
        (3) find the current in each path and then add the paths together.

    c. Total current in a parallel circuit may also be computed by:

        (1) taking the average amperage from readings at three points in the circuit.
        (2) using Ohm's Law with total resistance and total applied voltage.
        (3) subtracting the resistance from the applied voltage.

d. Since total resistance in a parallel circuit is always less than any one resistance, computing total resistance of parallel loads requires use of the following formula:

(1) $1/R_T = 1/R_1 + 1/R_2 + 1/R_3$ etc.
(2) $R_T = R_1 + R_2 + R_3$ etc.
(3) $1/R_T = R_1 - R_2 - R_3$ etc.

21. Complete statements about using Ohm's Law to find values in series-parallel circuits. Circle the number in front of the information that best completes each of the following statements.

a. Combinations of series and parallel loads are handled by:

(1) adding the loads and comparing them to applied voltage.
(2) combining parallel resistances into a single resistance, and then adding series resistances they are in series with.
(3) simply adding all resistances together.

b. To determine total resistance of a combination circuit, usually begin by combining resistances in the parts of the circuit shown in the diagram to be:

(1) farthest from the power source.
(2) nearest to the power source.
(3) in the series circuitry of the combination circuit.

c. Voltage drop across loads in a series-parallel circuit varies from source voltage:

(1) only in parallel parts of the circuit.
(2) only in series parts of the circuit.
(3) only when either circuit contains a transformer.

Written Test

22. Complete statements about applications of electronics in ACR control systems. Write in the word(s) that best completes each of the following statements.

    a. The increasing worldwide use of computer technology is evidenced in the increasing number of ACR control systems that make extensive use of ________________ electronic devices.

    b. Advances in electronic technology have led to the production of smaller ACR control devices each year, and although ____________________ , the devices are capable of more functions.

    c. Electronic _______________ and electronic fluid-control valves are popular applications in modern ACR control systems because they can fit in smaller spaces and still perform more functions than previous models.

    d. Because electronic activity inside semiconductors cannot be observed, their increasing use in electronic devices makes it extremely important for modern ACR service technicians to know electrical________________ and how to effectively use ___________________ instruments.

Permission to duplicate this test is granted.

Fundamentals of Electricity
Unit 1

Unit Evaluation Form

Student Name____________________________Date_______Unit Rating_______

Assignment Sheet 1–Convert Electrical Measurements to Basic Units Rating_________

Comments:

Assignment Sheet 2–Use Ohm's Law to Determine Unknown Values in Resistive Circuits Rating_________

Comments:

Other:

Written Tests:____________ Pretest____________ Posttest__________

Total__________

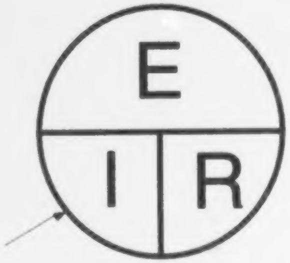
Teacher Signature Date__________

Student Signature Date__________

Permission to duplicate this form is granted.

Ohm's Law

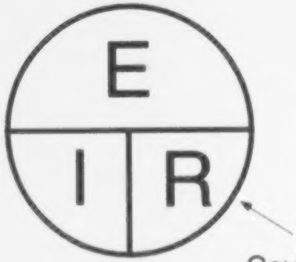
$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$



Cover up "I"

$$I = \frac{E}{R}$$

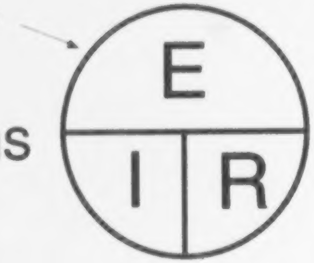
$$\text{Ohms} = \frac{\text{Volts}}{\text{Amperes}}$$



Cover up "R"

$$R = \frac{E}{I}$$

Cover up "E"



Volts = Amperes x Ohms

$E = I \times R$

Tools, Materials, and Test Instruments
Unit 2

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan enrichment of exceptional students as well as accommodation of special needs students.
4. Add graphic materials or overhead transparencies as needed.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement and personalize the unit. Reinforce basic skills when applicable.
10. Discuss and demonstrate the assignment and job sheets. Review criteria for evaluating these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of written test. Add or modify test items as needed.
13. Give written test.
14. Compile assignment sheet ratings, job sheet ratings, and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets added to the unit.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: a SCANS Report for America* 2000. These SCANS skills and competencies have been adapted by MAVCC to help instructors and program planners effectively articulate curriculum.

1. Find an air conditioning service firm owner or a service technician from your area to talk to the class about the importance of knowing how to use test instruments and the importance of knowing which instrument to use for a given problem and how to adjust instruments that require range settings or zeroing. **Basic skills, listening.**

2. Invite the same or similar person as referenced in item 1 to talk to the class about some of the tricky problems that a service technician confronts on the job, and how checking fuses and other electrical components can avoid wasting time on problems that may actually be related to something as simple as a simple electrical check with the proper meter. **Basic skills, listening.**

3. Group students into teams and then assign each team to visit a local company or individual's shop to learn about specific problems related to motors and how those problems are handled. Have students ask questions about handling customers who may be faced with the expense of replacing a bad compressor or other relatively expensive component. Have students prepare short reports about the local responses. **Interpersonal skills, teamwork.**

4. Note the importance of keeping records while troubleshooting electrical problems or compressor motors and stress this as a part of both company bookkeeping and customer relations. Review the job sheets where information has to be recorded and show students specifically why this information is critical to good service. **Information, acquisition and evaluation.**

Resources Used in Developing This Unit

1. Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.

2. Mackert, Howard and Russell Heiserman. *Automotive Electronics.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1988.

3. Smreker, Eugene and King Calvert. *Major Appliance Repair.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1987.

4. *The Air Conditioning, Heating and Refrigeration News HVACIR Source Guide.* Troy, MI: Business News Publishing Company, 1995.

5. Wantiez, Gary W. *ACR Electrical Components and Systems.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.

Suggested Activities

Suggested Supplemental Resources

Carrier's modular-based general training programs are excellent sources for students beginning their study of electricity. Illustrations in the modules are in full color and further enhanced with available VHS video materials, slide/audio programs, and cassette tapes. Many of the modules would serve well to supplemental materials in ACR Electrical Systems, and among them, with their Carrier ID numbers, are:

Introduction to Electricity GTE2-1
Electrical Components and Their Symbols GTE2-2
Wiring Diagrams GTE2-3
Wiring Diagram Exercises GTE2-4
Electric Meters and Their Uses GTE2-5
Alternating Current Fundamentals GTE2-6

The modules are available with a quantity discount for vo-tech schools and certain other training facilities. For information, the Carrier FAX is 315-432-3418, or write to:

Carrier
Literature Services Bldg. TR-8
P.O. Box 4808
Syracuse, NY 13221

Suggested Activities

Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Option A

4–Can perform job with no additional training.
3–Moderately skilled–Has performed job during training program; limited additional training may be required.
2–Limited skill–Has performed job during training program; additional training is required to develop skill.
1–Unskilled–Is familiar with process but is unable to perform job.

Option B

Yes–Can perform job with no additional training.
No–Is unable to performn job.

Tools, Materials, and Test Instruments
Unit 2

Answers to Assignment Sheets

Assignment Sheet 1

a. 125v
b. 25V
c. 240V
d. 25V
e. 0V
f. 450V
g. 22V to 23V
h. 225V
i. 110V to 115V
j. 45V

Assignment Sheet 2

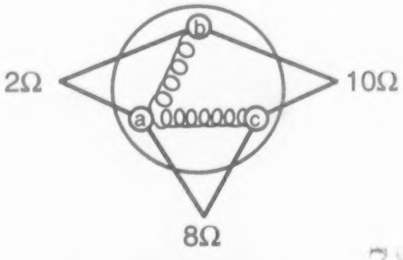
a. 3A
b. 11A
c. 30A
d. 40A
e. 150A

Assignment Sheet 3

a. 3Ω
b. 130,000Ω
c. 700Ω
d. 10,000Ω
e. 13Ω
f. 300Ω
g. 1Ω
h. 10Ω
i. 1,300Ω
j. 70,000Ω

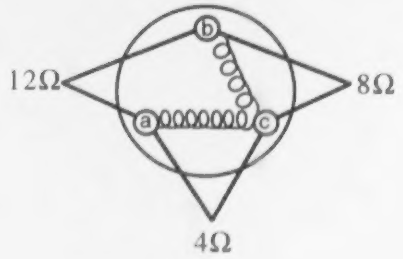
Assignment Sheet 4

a.
    a. Common
    b. Run
    c. Start

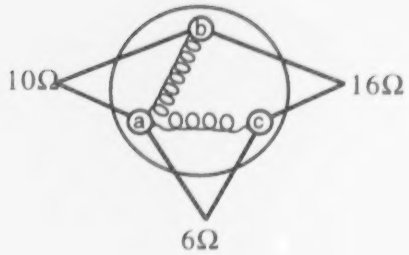


Answers to Assignment Sheets

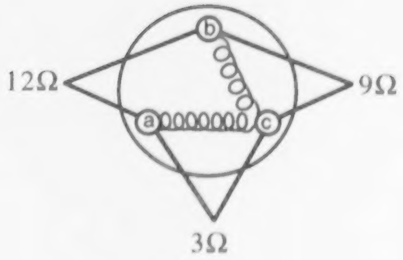
b.
- a. Start
- b. Run
- c. Common


b
12Ω
8Ω
a
c
4Ω

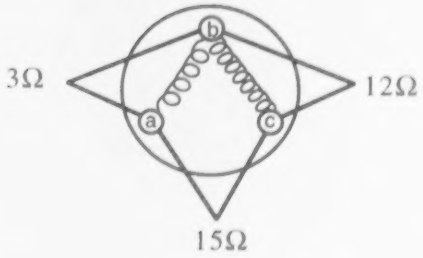
c.
- a. Common
- b. Start
- c. Run


b
10Ω
16Ω
a
c
6Ω

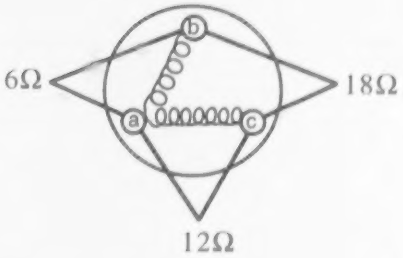
d.
- a. Start
- b. Common
- c. Run


b
12Ω
9Ω
a
c
3Ω

e.
- a. Run
- b. Common
- c. Start

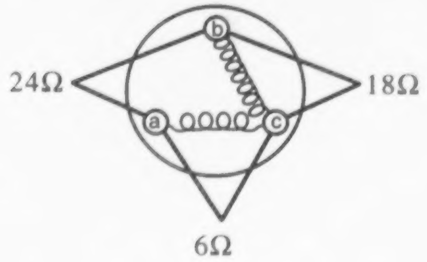

b
3Ω
12Ω
a
c
15Ω

f.
- a. Common
- b. Run
- c. Start

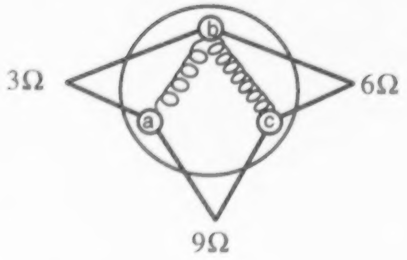

b
6Ω
18Ω
a
c
12Ω

Answers to Assignment Sheets

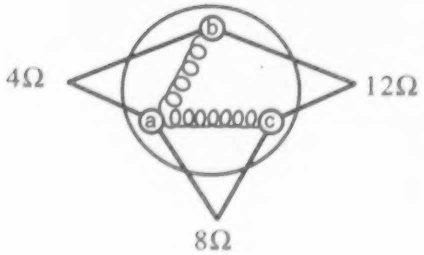
g. a. Run
b. Start
c. Common


b
24Ω
18Ω
a
c
6Ω

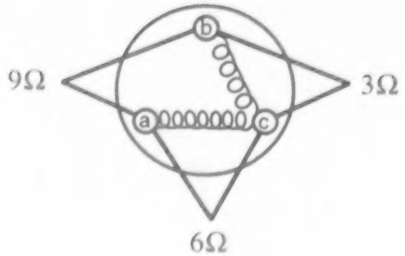
h. a. Run
b. Common
c. Start



i. a. Common
b. Run
c. Start


b
4Ω
12Ω
a
c
8Ω

j. a. Start
b. Run
c. Common



Tools, Materials, and Test Instruments
Unit 2

Answers to Written Test

1. a. 3
   b. 5
   c. 2
   d. 1
   e. 4

2. a. cut, strip, crimp
   b. staples, nails
   c. terminals
   d. hammers
   e. insulated, electrical shock

3. a. (1)
   b. (2)
   c. (1)

4. a. increases
   b. (1) terminals
      (2) Crimp-on
      (3) soldered
      (4) Wire
      (5) Terminal
   c. 60%, 40%
   d. sleeves, tape
   e. (1) stretch
      (2) humidity
      (3) ultraviolet
      (4) corrosive

5. a, c, d, f

6. a. in the direction
   b. crimp, solder
   c. crimp, solder
   d. Terminal kits

7. a, b, c

8. a. (1)
   b. (3)

9. a. much, where
   b. safety
   c. 10, 10
   d. open
   e. path
   f. lights
   g. through the insulation

Answers to Written Test

10. a. (1)
    b. (2)
    c. (2)
    d. (2) (a reading of ∞ would indicate an open)

11. a, b, c, d (all answers are true)

12. a. S
    b. R
    c. S
    d. S, R
    e. short
    f. grounded

13. a. clamp-on
    b. series
    c. milliamps
    d. do not, clamped
    e. hundred
    f. only one
    g. divide, through
    h. left, ten

14. a. (2)
    b. (3)
    c. (2)

15. a, b, d, e

16. a. Pay attention
    b. involuntary
    c. live
    d. dry, nonconductive
    e. coworker
    f. one hand
    g. all
    h. tag and lock

17. a. (2)
    b. (2)
    c. (1)
    d. (1)

Tools, Materials, and Test Instruments
Unit 2

Written Test

Name______________________________ Date__________ Score_________

1. Match each term on the right with its correct definition.

___ a. A classification system for identifying wire conductors by diameter and number

___ b. A component or circuit electrical problem in which the path comes in contact with the chassis or some other component

___ c. Guidelines dedicated to the protection of life and property in the uses and functions of electrical materials in residential and commercial applications

___ d. An electrical problem in which current is diverted from its intended path into a path of lower resistance and which often blows a fuse or trips a breaker

___ e. An electrical problem in which the path of a circuit has been interrupted

1. Short
2. NEC
3. AWG
4. Open
5. Ground

2. Complete statements about tools. Write in the word(s) that best completes each of the following statements.

a. Wire strippers/crimpers come in a variety of types and are used to ______________ electrical wires, to ______________ insulation from around wires, and to ______________terminals onto wires.

b. Lineman's pliers are used for a variety of jobs such as cutting wires, driving and pulling ____________ or ____________, gripping objects, and stripping wires.

c. Soldering tools of different sizes and ratings are used to solder wires together or to solder ______________ to the ends of wires.

d. A variety of hand tools such as assorted sizes and types of screwdrivers, pliers, and ____________ are useful in working with electrical components.

e. Tools of any kind used in electrical work must have ____________ handles to prevent ______________ ____________ when working with "live" circuits or when a "dead" circuit turns out to be "live."

Written Test

3. Solve problems about electrical wiring. Circle the number in front of the information that best solves each of the following problems.

   a. A coworker holding two wires notes that one of the wires is larger in diameter than the other, and suggests that the AWG number for the larger diameter wire will be larger than the AWG number for the small diameter wire. The problem is:

      (1) The coworker has it backward; it should be "the smaller the number, the larger the wire."
      (2) The coworker is actually talking about ampacity.

   b. You know that wire delivered to a job site has to be suitable for wet conditions. You check the wire and find only RH stamped on the insulation. The problem is:

      (1) RH indicates only a heat rating; it has nothing to do with wet locations.
      (2) The wire should have a "W" in its ID to indicate that it is suitable for wet conditions.

   c. You are discussing a wire that has 10/3 on it and a coworker tells you that the stamp means it is a 10-gauge wire rated for 30 amps and no more. The problem is:

      (1) It is a 10-gauge AWG wire, but the 3 means there are three conductors in the wire and has nothing to do with an amperage rating.
      (2) It is a 10-gauge AWG wire, but the 3 literally means the wire should not exceed an application where more than 3 amps would be applied.

4. Complete statements about connecting electrical wires. Write in the information that best completes each of the following statements.

   a. Wires must be properly connected to each other and to components to prevent overheating or voltage drops because a loose connection ____________ resistance.

   b. Electrical wires are connected to components or other wires in a variety of ways such as:

      (1) Screw ______________________.
      (2) ___________-__________ terminals.
      (3) Splices and _____________ splices.
      (4) __________________ nuts.
      (5) __________________ blocks.

Written Test

c. Wire splices or other soldered electrical connections are often made with rosin-core 60/40 solder which is an alloy of _______ tin and _____ lead and has rosin flux inside the solder.

d. Most connections must be insulated with insulation _______________, insulating _____________, or some other insulating product.

e. Tape used for insulating conductors includes plastic, rubber, glass cloth, and other materials rated for a variety of factors such as:

(1) _______________ characteristics.
(2) _______________ and temperature resistance.
(3) _______________ ray resistance.
(4) _______________ and other wear conditions.

5. Select true statements about guidelines for splicing wires. Place an "X" beside each true statement.

__ a. Before wires can be properly spliced, insulation must be stripped from the conducting wire.

__ b. Wire stripping is so simple it really does not require much practice.

__ c. Wires may be spliced together using a variety of twisting techniques.

__ d. After splicing, solder can be added to give the splice more strength and less resistance.

__ e. Screw-on wire nuts work well on splices if used properly, but they also require taping so they will be properly insulated.

__ f. Wire nuts and some other solderless connectors are often color coded to identify the gauge of wire they are designed to be used with.

__ g. Before applying wire nuts, wire splices can be soldered to add strength although it may increase resistance slightly.

6. Complete statements about connecting wires to terminals. Write in the information that best completes each of the following statements.

a. To attach bare wire to a screw terminal, loop the wire around the screw ______ ______ __________ the screw turns to avoid having the wire slip out from under the screw when you tighten the screw.

b. When greater stability is desired, ________ or _________ a terminal lug onto the end of the wire.

Written Test

c. Use a similar technique to ____________ or ______________ a spade or push-on terminal onto the end of a wire.

d. ____________ _____________ are available with a wide variety of solder or solderless terminals for use in making electrical connections.

7. Select true statements about test instrument characteristics. Place an "X" beside each true statements.

___ a. Selection of a test instrument depends upon the type of work you are doing, the type of equipment you are checking, and what you want to find out about the equipment.

___ b. Basic test instruments include meters for checking voltage, meters for checking amperage, and other meters for checking resistance.

___ c. There are specialized test instruments for checking capacitors, hermetic motors, power consumption or watts, and other functions.

___ d. A test instrument contains only one meter and performs only one function.

8. Solve problems about reading test instruments. Circle the number in front of the information that best completes each of the following problems.

a. You are working with an analog meter in a situation where accuracy is critical. You're having a problem remembering how to read an analog meter, so you should:

(1) Set the meter for the scale you want to measure and try to read from the center two thirds of the scale to get the greatest accuracy.
(2) Set the meter for a scale slightly above or below what you intend to measure so the needle will always point close to the center.
(3) Set the meter for the scale you want to measure, and if the reading is difficult to make, interpolate.

b. You are working with a digital meter that has been giving erratic readings, and finally you attempt to use the meter and it will not zero. The problem is:

(1) The meter is bad and should be discarded.
(2) The meter has probably been dropped and needs to be sent in for repair.
(3) The meter probably needs a new battery.

Written Test

9. Complete statements about using voltmeters and voltage testers. Write in the word(s) or information that best completes each of the following statements.

   a. Voltmeters and voltage testers indicate if voltage is present, and if so, how ________________ and __________________.

   b. Knowing if voltage is present or not can be an important ___________ factor as well as useful in diagnosing problems.

   c. Knowing how much voltage is present is important because a motor or other load will usually not work properly if voltage available is less than _____________ percent below its rating and will often "burn up" if voltage in excess of _______________ percent above its rating is applied.

   d. Identifying where voltage is present in a circuit is also important because this can be used to identify which components are _________________ or where the circuit is broken.

   e. Voltmeters give a reading when the two probes are placed on the wiring of a circuit so as to complete a __________________ through the meter.

   f. Other voltage testers use ____________________ to indicate the presence of voltage, or even different lights, or a change in the intensity of the lights to indicate levels of voltage.

   g. Some voltage testers will have two probes like a meter; others will have a single probe, and some do not actually have to come in contact with the conductors, but read "______________________
   _______________ __________________________."

10. Solve problems about using ohmmeters. Circle the number beside the information that best solves each of the following problems.

    a. A technician checking a component with an ohmmeter is checking for continuity and does get a continuity reading between wiring and the shell of the motor. The technician may have a continuity reading, but the problem is:

       (1) this particular continuity reading is where there should be no continuity, and it indicates a ground.

       (2) this particular continuity reading is where there should be no continuity, and indicates an open.

Written Test

b. A technician suspects a circuit is open, but the ohmmeter shows a resistance much higher than the one specified for the component. The problem is:

(1) the circuit is both grounded and shorted and requires more troubleshooting.
(2) the circuit is shorted.

c. A technician checking a component first gets a reading of ∞ and then a reading of 10 megohms, and the technician interprets the readings to indicate that the meter is out of whack. The problem is:

(1) the meter was probably not zeroed.
(2) the reading is typical of an open, and the meter is probably working okay.

d. A technician checking for continuity suggests that it will be difficult to check because the specified resistance of the component is not known. The problem is:

(1) any reading at all indicates continuity.
(2) a reading from zero to very high will still indicate continuity.

11. Select true statements about using ohmmeters to check motors. Place an "X" beside each true statement.

___ a. When the condition of a motor is unknown or when the wiring diagram is missing, ohmmeter checks will indicate valuable service information about the motor.

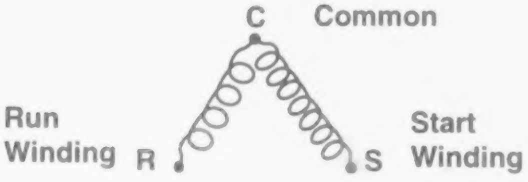
___ b. A motor which has a single winding with two leads or terminals only be checked for an open or a ground.

___ c. A multispeed motor can also be checked for an open or ground, but on a multispeed motor or any motor with more than one winding, the windings themselves can be identified by resistance readings.

___ d. The most common application of ohmmeters in checking motors is in checking hermetic compressor motors.

Written Test

12. Complete statements about checking a hermetic compressor with an ohmmeter. Reference the following illustration and write in the correct information for the procedure.



a. Place the ohmmeter probes at C and _____ to read the start winding resistance.

b. Place the probes at C and _____ to read the run winding resistance.

c. Place the probes at R and _____ to read the combined resistance of both windings.

d. If the readings from C to S plus the readings from C to R equals the reading from ______ to ______, the motor is operational.

e. If two of the resistance readings combined do not come very close to equalling the third resistance readings, it indicates a ______________.

f. Continuity between any of the terminals and the shell of the compressor indicates a ______________ compressor.

13. Complete statements about using ammeters. Write in the word(s) or information that best completes each of the following statements.

a. There are two types of ammeters, in-line and ____________________ - ____________.

b. In-line ammeters are often found in VOMs and multimeters, and must be connected in ________________ with the load.

c. In-line ammeters will usually read current from ____________________ to a maximum of 10 amps.

d. Clamp-on ammeters __________ ____________ actually connect to the circuit in any way, but are ____________________ around one of the conductors in the circuit, and read current by measuring the magnetic field around the wire.

Written Test

e. Clamp-on ammeters come with scales ranging from 0-6 amps up to scales that will read several ____________________ amps.

f. Be sure to clamp the jaws of the meter around ____________________ ____________ conductor in order to get a proper reading.

g. To make reading low amperage easier, wrap a single conductor through the ammeter jaws several times to magnify the reading, then ____________ the meter reading by the number of times the conductor passes ________________ the jaws to find the correct resistance.

h. Many service technicians carry a "10-wrap" coil to check very low amperage readings because the reading can be converted by simply moving the decimal one place to the ____________ to divide by ____________.

14. Solve problems about useful test accessories. Circle the number in front of the information that best solves each of the following problems.

a. A technician needs to apply power to an isolated load to check the load. The technician starts to unplug other components in the system. To better solve the problem, the technician should:

(1) unplug other loads because it will not change the characteristics of the load being checked.
(2) use a cord with a male or female plug on one end and alligator clips on the other end so power can be applied directly to the load.
(3) remove the load and bench test it with an ohmmeter.

b. A technician is faced with the problem of finding a broken wire and is spending a great deal of time trying to look for the break. The better solution to the problem is to:

(1) rewire the suspected part and check it out.
(2) start at the component end of the wire and check back to the power supply with an ohmmeter.
(3) use jumper wires with alligator clips to temporarily bypass the broken path.

c. A technician keeps turning the system on and off to check out a component. To better solve the problem, the technician should:

(1) unplug the component and bench test it.
(2) check the component itself with a temporary control made out of a switch with alligator clips attached to the other end.
(3) simply use jumper wires—they're really all-purpose test instruments.

Written Test

15. Select true statements about the effects of current on the human body. Place an "X" beside each true statement.

___a. Never underestimate the potential danger of electricity.

___b. Current as low as 50 milliamps (50 thousandths of an ampere) can cause heart convulsions and death.

___c. Even a 24V circuit will carry a current of .1A to .2A, which is 100 to 200 milliamps, which could cause discomfort, but probably not cause injury.

___d. The potential for much more current and increased danger is present with higher voltages.

___e. Higher voltages and currents also present a danger of creating a situation called arcing, where an electrical arc literally jumps a gap and goes through your body to ground.

16. Complete statements about how to avoid electrical accidents. Write in the word(s) or information that best completes each of the following statements.

a. ____________ ____________________ because most electricial accidents happen through carelessness or misuse.

b. Remember that the ___________________________ reaction to electrical shock can cause you to injure yourself or others.

c. Work on _______________ circuits only when absolutely necessary.

d. Stand on ________________, nonconductive surfaces, or wear shoes with dry, ______________________________ soles when working with live circuits.

e. Work with a __________________ whenever possible when working with live circuits.

f. Use _____________ _______________ only when working with live circuits.

g. Assume ___________ circuits are live unless you have personally checked for voltage immediately prior to working on the circuit.

h. Use ____________ ____________ ______________ procedure to insure that circuits will not be reenergized while service is underway.

Written Test

17. Complete statements about rescue procedures for electrical accidents. Circle the number in front of the statement that best completes each of the following statements.

    a. You have just witnessed an electrical accident involving a coworker who appears to be in contact with a live circuit of some kind. The very first thing you should do is:

        (1) Try to break the person's contact with the circuit.
        (2) Try to turn off the power, if you can locate it.

    b. In case of an electrical accident, the second thing you should do is:

        (1) Notify emergency personnel.
        (2) Decide if it would be easier to move the person being shocked or easier to remove the conductor that is in contact with the person.

    c. A definite precaution to employ when helping someone involved in an electrical accident is to:

        (1) Stay out of contact with the person or anything around the person that might be in touch with the source of the electricity.
        (2) Never walk within a distance close enough that the person involved in the accident could reach out and touch you.

    d. You know that touching a person in an electrical accident will only make you part of the problem, so to separate the person from the electrical conductor, you should:

        (1) Use a dry, nonconductive object such as a board, rubber mat, or even several thicknesses of cloth or paper.
        (2) Use only a long, dry stick or board that will keep you safely away from the person.

Permission to duplicate this test is granted.

Tools, Materials, and Test Instruments

Unit 2

Unit Evaluation Form

Student Name______________________________Date________ Unit Rating______

Assignment Sheet 1—Read a Voltmeter Comments:	Rating _____
Assignment Sheet 2—Read an Ammeter Comments:	Rating _____
Assignment Sheet 3—Read an Ohmmeter Comments:	Rating _____
Assignment Sheet 4—Identify Start, Run, and Common Terminals and Draw the Windings of a Split-Phase Motor Comments:	Rating _____
Job Sheet 1—Solder Terminals Onto Wires Comments:	Rating _____
Job Sheet 2—Splice Wires Using Wire Nuts Comments:	Rating _____
Job Sheet 3—Use Digital and Analog Voltmeters to Check Power Sources Comments:	Rating _____

Unit Evaluation Form

Job Sheet 4—Use an Ohmmeter to Check Continuity of Fuses Rating _____

Comments:

Job Sheet 5—Use an Ohmmeter to Determine the Resistance of Resistors Rating _____

Comments:

Job Sheet 6—Use an Ohmmeter to Identify Terminals and Electrical Condition of a Hermetic Compressor Rating _____

Comments:

Job Sheet 7—Use an Ammeter to Start and Run Amperage of a Motor Rating _____

Comments:

Other:

Written Tests _________ Pretest ________ Posttest ___________

Total ___________

Student Signature ______________________________________ Date _____

Teacher Signature ______________________________________ Date _____

Permission to duplicate this form is granted.

Electrical Power
Unit 3

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan enrichment of exceptional students as well as accommodation of special needs students.

4. Make transparencies to enhance presentation of objectives:

   TM 1—Electrical Transmission (Objective 4)
   TM 2—Watt's Law (Objective 9)

5. Develop teaching plan. Adjust for different learning styles.

6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.

9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.

10. Discuss and demonstrate the assignment and job sheets. Review criteria for evaluating these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

12. Make copies of written test. Add or modify test items as needed.

13. Give written test.

Suggested Activities

14. Compile assignment sheet ratings, job sheet ratings, and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets added to the unit.

15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: a SCANS Report for America 2000.* These SCANS skills and competencies have been adapted by MAVCC to help instructors and program planners effectively articulate curriculum.

1. Enhance the early objectives in this unit by having a representative from a local power company talk to the class about power generation, where the generation facilities for the area are located, what form of energy the generating facility uses, and the types of transformers used in the process of transmission. **Basic skills, science and listening.**

2. When discussing Objective 3, discuss the type of power supplied to your own ACR lab/classroom, and show students where the service is located and what it looks like. If possible, have samples of three-wire and four-wire delta point-of-delivery transformers available to demonstrate how single and three-phase circuits are configured. **Basic skills, science and listening.**

3. Help prepare students for Assignment Sheet 2 activities by inviting a meter reader from a local utility or co-op to demonstrate to the class how electric watt-hour meters work and how to read them. Ask the meter reader to demonstrate not only how to read the meter, but how the reading is recorded for billing purposes. **Basic skills, science and listening.**

4. Assign individual students the task of finding out about the electric service at their home or residence, where the power is initially generated, approximately how far it has to be transmitted to reach a local user, what the cost per KWH is, and what type of meter is used to keep track of consumption. Have students report their findings to the class. **Basic skills, listening, writing, and speaking.**

Suggested Activities

Resources Used in Developing This Unit

1. Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.
2. *The Air Conditioning, Heating and Refrigeration News HVAC/R Source Guide.* Troy, MI: Business News Publishing Company, 1995.
3. Wantiez, Gary W. *ACR Electrical Components and Systems.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.
4. Smreker, Eugene and King Calvert. *Major Appliance Repair.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1987.

Suggested Supplemental Resources

Two important websites for ACR students and instructors are:
http://www.hvaconline.com and **http://www.environ.com/hvacmall.htm.**

With certain membership requirements, both of these sites permit you to input questions about ACR service and receive answers from professionals in every area from installation to all kinds of troubleshooting.

These sites can also be used to access news from professional HVAC organizations, some of which are listed here:
Air Conditioning and Refrigeration Institute–**http://www.ari.org** Air Conditioning Contractors of America–**http://www.acca.org** American Society of Heating, Refrigerating, and Air Conditioning Engineers–**http://www.ashrae.org**

Suggested Activities

Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Option A

4–Can perform job with no additional training.
3–Moderately skilled–Has performed job during training program; limited additional training may be required.
2–Limited skill–Has performed job during training program; additional training is required to develop skill.
1–Unskilled–Is familiar with process but is unable to perform job.

Option B

Yes–Can perform job with no additional training.
No–Is unable to perform job.

Electrical Power
Unit 3

Answers to Assignment Sheets

Assignment Sheet 1

a. 14,400 watts or 14.4kw
b. 4,800 watts or 4.8kw
c. 24,000 watts or 24kw
d. 30,000 watts or 30kw
e. .96 watts

Assignment Sheet 2

a. 7125
b. 7800
c. 675

Electrical Power
Unit 3

Answers to Written Test

1.
   - a. 3
   - b. 7
   - c. 13
   - d. 9
   - e. 4
   - f. 1
   - g. 6
   - h. 8
   - i. 2
   - j. 10
   - k. 11
   - l. 12
   - m. 5
2.
   - a. mechanical motion
   - b. time rate
     - (1) one, one
     - (2) 3.413
     - (3) 746
3. a, b, e, f
4.
   - a. (4)
   - b. (1)
   - c. (2)
   - d. (2)
   - e. (2)
5.
   - a. (1)
   - b. (2)
   - c. (2)
   - d. (1)
   - e. (1)
   - f. (5)
   - g. (2)
6. a, b, d, e, f
7.
   - a. supply
   - b. (1) fuses
     - (2) wiring
     - (3) starting, starting
     - (4) lower
     - (5) breakdown
   - c. (1) transformer
     - (2) undersize
     - (3) long
     - (4) poor
     - (5) series
8. a, b, c, d

Answers to Written Test

9. a. (2)
   b. (2)
   c. (2)

10. a. kilowatts
    b. KWH
    c. efficiently, specifications
    d. wattmeter
    e. wattmeter
    f. power factor
    g. power factor, Pf
    h. Power factors
       (1) 1.0
       (2) .75
       (3) .35

11. a. (2)
    b. (1)
    c. (3)

Electrical Powwer
Unit 3

Written Test

Name________________________________Date_______Score ____________

1. Match each term on the right with its correct definition.

____ a. A meter which indicates the number of kilowatt hours used in a given amount of time

____ b. Usually a green-colored or bare wire conductor connected to an equipment case and to an intentional ground for safety purposes

____ c. Usually a green-colored or bare wire system or circuit conductor which is intentionally grounded for safety purposes

____ d. Term used to designate each hot conductor of a power supply

____ e. Usually a white current-carrying conductor connected to the center tap of a transformer which carries current only when an electrical device is operating

____ f. In a circuit, it is a current-carrying conductor where voltage is always readable, and should be any color other than white, neutral gray, or green

____ g. Voltage supplied to the input or primary winding of a transformer

____ h. Output voltage or voltage that is supplied from the secondary side of a transformer

____ i. Alternating current with no more than two hot conductors

____ j. A transformer which decreases secondary voltage

____ k. A transformer which increases secondary voltage

____ l. Alternating current with three hot conductors

____ m. The fundamental unit of measure for electrical power

1. Hot conductor
2. Single-phase
3. Electric watt-hour meter
4. Neutral
5. Watt
6. Primary voltage
7. Equipment ground
8. Secondary voltage
9. Leg
10. Step-down transformer
11. Step-up transformer
12. Three-phase
13. Ground conductor

Written Test

2. Complete statements about characteristics of electrical power. Write in the information that best completes each of the following statements:

   a. To make life more comfortable, we use electrical power by converting it into such things as heat, light, and _________________ __________________.

   b. Electrical power is the __________ ____________ at which a charge is moved by voltage and is measured in watts:

      (1) One watt equals the work accomplished in ________ second by _______ volt of potential difference in moving one coulomb of charge.

      (2) One watt of electrical power equals ___________ Btus of heat.

      (3) ____________watts equals one Hp.

3. Select true statements about transformers. Place an "X" beside each true statement.

   ___ a. In order for electrical power to be used for heat, light, mechanical motion, and other uses, the proper voltage and current must be delivered over long distances to the home or business where it is needed.

   ___ b. Step-up transformers increase voltage at the point of generation, and step-down transformers decrease voltage at various other points in the delivery system.

   ___ c. Increasing the voltage in turn increases the current which allows electrical power to be easily transmitted over long distances with relatively large transmission cable, since wire carrying capability is based on amperes.

   ___ d. Transformers within equipment are often used to reduce voltage even farther, down to 24 volts, 12 volts, or even 2.5 volts, but step-down transformers are seldom used within equipment.

   ___ e. Transformers within equipment may increase voltage to as much as 5,000V DC for use with such devices as electronic air cleaners.

   ___ f. AC voltage may be converted by rectifiers within equipment to low level DC voltages, 5V, 10V, or 15V for use in electronic circuits.

Written Test

4. Complete statements about power distribution. Circle the number in front of the information that best completes each of the following statements.

    a. Electrical power begins at the power plant where electrical power is generated by:

        (1) falling water.
        (2) burning coal or gas.
        (3) nuclear power.
        (4) all of the above.

    b. To immediately increase the voltage to as much as 345,000 volts in preparation for transmission, a power plant uses:

        (1) step-up transformers.
        (2) step-down transformers.

    c. Transmission cables carry the power across country to regional substations where the voltage is reduced to as low as 4,000 volts by:

        (1) step-up transformers.
        (2) step-down transformers.

    d. Transmission cables within the city or area carry the power to residential and commercial/industrial customers using nearby power poles and:

        (1) step-up transformers.
        (2) step-down transformers.

    e. To provide voltage at a level that customers can use, the transformers referenced in the previous question must:

        (1) maintain the voltage.
        (2) reduce the voltage.
        (3) increase the voltage.

Written Test

5. Complete statements about power supplies. Circle the number in front of the information that best completes each of the following statements.

    a. Residential and small commercial applications usually require only single-phase current in voltages ranging from:

        (1) 120 to 240.
        (2) 440 to 550.

    b. Commercial and industrial applications may require three-phase current in:

        (1) separate services.
        (2) various combinations of voltages from 120V to 600V.

    c. Three-phase power can be used to supply single-phase power:

        (1) and single-phase power can be converted to three-phase power.
        (2) but single-phase cannot be converted into three-phase power.

    d. Using three-phase current to power motors causes fewer service motor problems:

        (1) and avoids frequent requirements for starting components on single-phase motors,
        (2) and saves a great deal of money on electricity.

    e. On the other hand, with three-phase current, voltage has to be:

        (1) kept in balance on all three legs.
        (2) regulated by a step-down transformer.

    f. Point-of-delivery transformers provide single- and/or three-phase current in various combinations of voltages:

        (1) a three-wire delta transformer has one three-phase and three single-phase circuits with 240V, 440V, or 550V.

        (2) a four-wire delta transformer has two 120V single-phase circuits, one 240V three-phase circuit, and three 240V single-phase circuits.

        (3) the three legs include a "wild-leg" or "stinger-leg" as it is sometimes called, which has a voltage of approximately 200V which should **never** be used for single-phase 120V power.

        (4) a four-wire wye transformer has three 120V or 277V single-phase circuits, three 208V or 480V single-phase circuits, and one 208V or 480V three-phase circuit.

        (5) all of the above.

Written Test

g. Three-wire delta transformers may be grounded or ungrounded and four-wire wye transformers require that for a ground, the transformer should:

(1) always use leg 1.
(2) use neutral.

6. Select true statements about delivery systems. Place an "X" beside each true statement.

__ a. Service to a home or small business delivers power from a step-down transformer on a power pole through a watt-hour meter to a breaker or fuse panel.

__ b. The breaker panel, also called a circuit box, must include a single main breaker or fused disconnect switch and a separate breaker or fuse for each circuit in the building.

__ c. 240V circuits will be in series and connected to one hot leg and to the ground.

__ d. Individual 120V circuits will be parallel and connected to one hot leg, to neutral, and to the ground.

__ e. The system should be grounded from the connections in the watt-hour meter to a copper-clad, iron stake, usually 8 feet long, driven into the ground.

__ f. The system may also be grounded to the cold-water piping in the building or through metallic conduit if it is used throughout the system.

7. Complete statements about problems with power delivery. Write in the word(s) or information that best completes each of the following statements.

a. Problems in the _____________ service as well as within the building electrical system can cause low supply voltage.

b. The effects of low supply voltage can be seen in such things as:
   (1) tripping breakers or blowing __________.
   (2) overheating of ___________ and/or motors.
   (3) motors having trouble ______________ or not ________________ at all.
   (4) equipment operating at ___________ efficiencies.
   (5) _____________________ of motors or other electrical components.

c. Typical causes of low supply voltage include, but are not limited to:
   (1) undersize _________________________.
   (2) ________________ wire.
   (3) __________ runs of wire.
   (4) __________ connections.
   (5) loads in ___________.

Written Test

8. Select true statements about power consumption. Place an "X" beside each true statement.

__ a. Electrical loads can be said to consume or "use up" electricity.

__ b. Power companies must determine how much electricity a load consumes in order to determine what to charge for the electricity.

__ c. A power company measures the rate of flow of electricity to a customer by comparing the amperage draw of the service with the voltage provided over a specified period of time.

__ d. The rate of flow, in effect, is the amount of heat, light, mechanical motion, or other work provided to the customer.

__ e. The rate of flow is measured in amperage consumed per hour.

9. Solve problems about Watt's Law. Circle the number in front of the information that best solves each of the following problems.

a. A coworker talking about Watt's Law tells you that the law is easy to remember because it is exactly like Ohm's Law and the formulas are even the same. To solve the problem, you should:

(1) Remind your coworker that Ohm's Law concerns itself with voltage, amperage, and resistance.

(2) Remind your coworker that Watt's Law has a different formula than Ohm's Law, in fact, it is $P = I \times E$.

b. You have a watts calculation, but you need to know current, and are not quite sure how to use Ohm's Law to make your calculation. To solve the problem, you should:

(1) Convert the watts back to voltage first.

(2) Use the Watt's Law circle just like the Ohm's Law circle to find an unknown value.

c. You need to find watts at one point in a troubleshooting routine, but you have only voltage and resistance to work with. To solve the problem, you should:

(1) Use voltage and resistance to make a good estimate of watts.

(2) Use Ohm's Law to determine current, and then use voltage and current to calculate watts.

Written Test

10. Complete statements about measuring power consumption. Write in the word(s) or information that best completes each of the following statements.

a. A power company measures energy usage by the customer with a watt-hour meter which usually reads in ____________________ per hour.

b. Power company charges are normally based on the monthly ________ reading on a watt-hour meter mounted on an electrical service entrance.

c. A service technician measures wattage to help determine how ____________________ or how close to ____________________ an appliance or component is operating.

d. A service technician may use a ____________________ to read watts, or use an ammeter and a voltmeter and Watt's Law to calculate watts.

e With a ____________________, conversion factors for determing watt consumption are built-in so the technician is free of risking mistakes in calculations.

f. A ______________ ____________ must be taken into consideration when using Watt's Law to calculate power consumption of motors or other inductive loads.

g. Watt's Law, including a ______________ ________________, is expressed by the formula:

$P = I \times E \times$ ______________.

h. ________________ ______________ for loads vary with the type of load:

(1) A resistive load has an approximate Pf of __________.

(2) Motors, have an approximate Pf of ____________.

(3) Magnetic coils such as relays, contactors, and solenoids have an approximate Pf of __________.

Written Test

11. Complete statements about reading a watt-hour meter. Circle the number in front of the information that best completes each of the following statements.

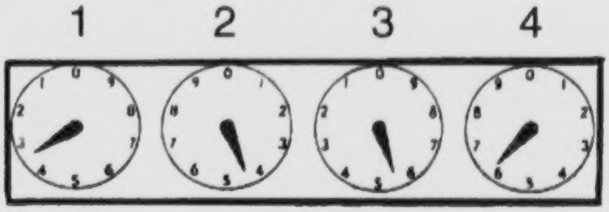
a. The difference between a digital and dial-type watt-hour meter is that:

(1) Only digital meters are used for commercial accounts.

(2) Dial-type meters require reading indicators on four different dials, and digital meters show the reading in plain numbers.

(3) Digital meters show everything in metrics, and dial-type meters are strictly analog.

b. Indicators on a dial-type watt-hour meter move counterclockwise or clockwise depending on the location of the dial in the four-dial arrangement. In the following illustration:



(1) Dial 1 moves counterclockwise, dial 2 moves clockwise, dial 3 moves counterclockwise, and dial 4 move clockwise.

(2) Dials 1 and 2 move counterclockwise, and dials 3 and 4 move clockwise.

(3) Dial 1 moves clockwise, dial 2 moves counterclockwise, dial 3 moves clockwise, and dial 4 moves counterclockwise.

c. To check the efficiency of a piece of electrical equipment, a service technician could:

(1) Read the watt-hour meter, then let the equipment run for an hour, then read the watt-hour meter again to see how much energy the equipment consumed.

(2) Complete everything in item (1), but be sure to conclude the check by comparing the energy consumption with nameplate rating information.

(3) Complete everything in items (1) and (2), and then compare everything with test instrument readings before making any conclusions.

Permission to duplicate this test is granted.

Electrical Power

Unit 3

Unit Evaluation Form

Student Name______________________ Date________ Unit Rating______

Assignment Sheet 1—Use Watt's Law to Determine Power Rating _____

Comments:

Assignment Sheet 2—Read an Electric Watt-Hour Meter Rating _____

Comments:

Job Sheet 1—Use a Wattmeter and an Ammeter to Determine Watts Rating _____

Comments:

Other:

Written Tests: ________ Pretest ____________ Posttest ____________

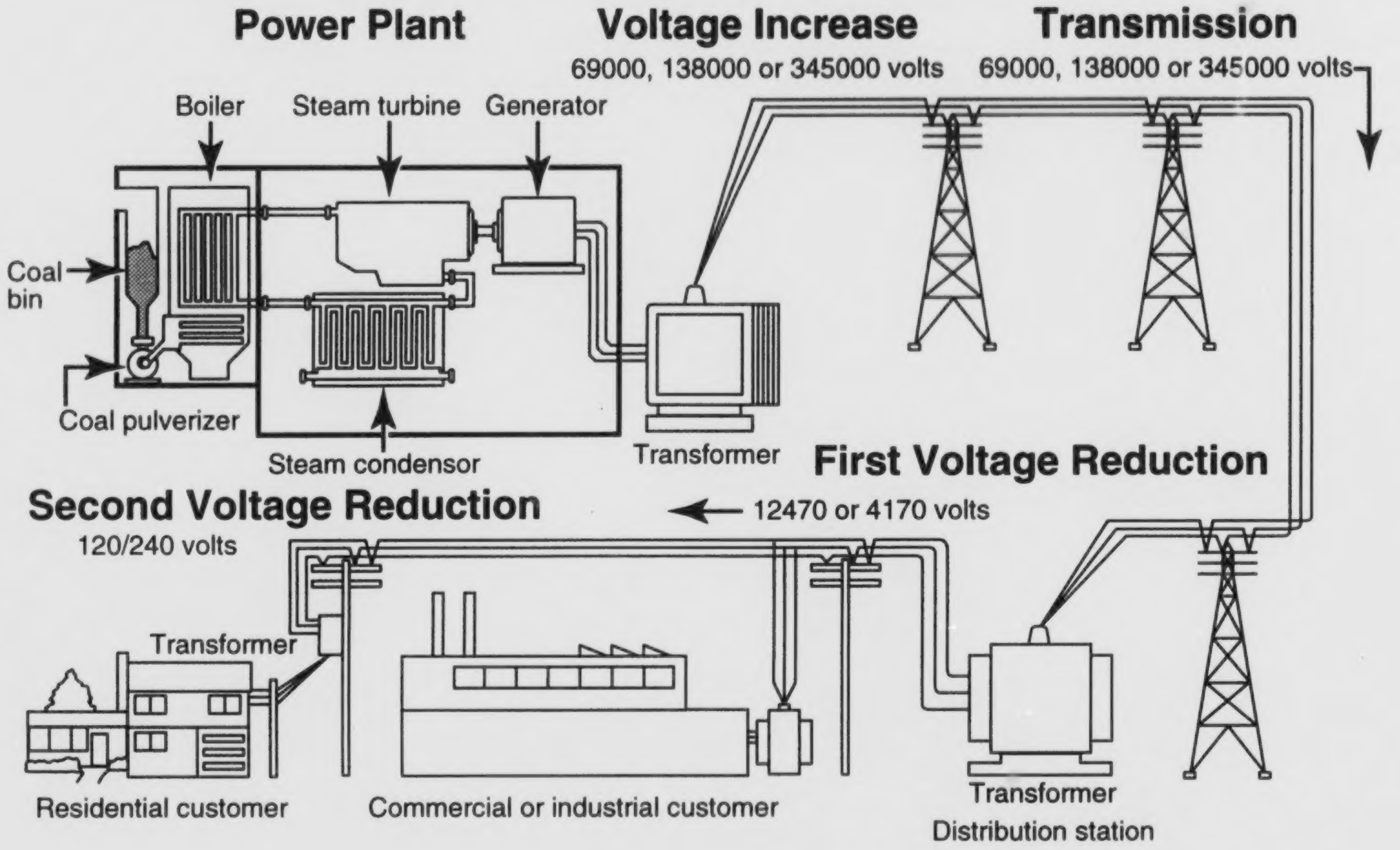
Total ____________

Student Signature ______________________________ Date _____

Teacher Signature ______________________________ Date _____

Permission to duplicate this form is granted.

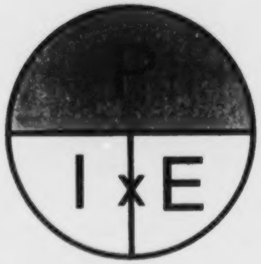
ELECTRICAL TRANSMISSION


Power Plant
Voltage Increase
69000, 138000 or 345000 volts
Transmission
69000, 138000 or 345000 volts
Boiler
Steam turbine
Generator
Coal bin
Coal pulverizer
Steam condensor
Transformer
First Voltage Reduction
12470 or 4170 volts
Second Voltage Reduction
120/240 volts
Transformer
Residential customer
Commercial or industrial customer
Transformer
Distribution station

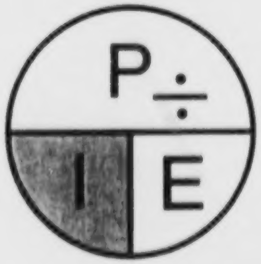
ACR Electrical Systems, Unit 3
Teacher Page 19

Watt's Law

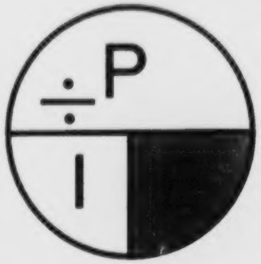
P (Power) = I (Volts) x E (Amperes)



I (Volts) = P (Power) ÷ E (Amperes)



E (Amperes) = P (Power) ÷ I (Volts)



Circuits, Symbols, and Diagrams
Unit 4

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan enrichment of exceptional students as well as accommodation of special needs students.
4. Add overheads or other graphic materials as desired to enhance instruction.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss and demonstrate the procedures in the job sheets. Review criteria for evaluating these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of written test. Add or modify test items as needed.
13. Give written test.
14. Compile job sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets added to the unit.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: a SCANS Report for America 2000.* These SCANS skills and competencies have been adapted by MAVCC to help instructors and program planners effectively articulate curriculum.

1. Locate available equipment to demonstrate the graphic materials discussed in Objectives 1, 2, and 3. Try to locate equipment that has an installation diagram so students can read the diagram in order to relate it to a specific operation. **Basic skills, listening and reading.**

2. Other than those in the text, have examples of pictorials and ladder schematics to use when discussing Objectives 4 and 5. Demonstrate how the two diagrams differ and also how they can complement each other in troubleshooting activities. **Basic skills, science, reading, and listening.**

3. Prepare the appropriate equipment for students to use when they build and test working models of the circuits presented in the job sheets. Impress students with the importance of understanding simple and complex circuits. Stress all elements of safety in building working models and in testing circuits. **Basic skills, listening and science.**

4. Impress upon students the importance of electrical troubleshooting in the scheme of customer service and how the ability to read and interpret pictorials and ladder schematics gives a service technician a certain confidence that customers notice and appreciate. **Information, acquisition and evalution.**

5. Assign students to small groups and have members of each group bring pictorials and ladder schematics or installation drawings from ACR equipment they find in their homes. Have the group present their findings to the class and concentrate on explaining why the equipment manufacturer included the type of diagrams they found. **Interpersonal skills, team work; basic skills, science and speaking.**

Resources Used in Developing This Unit

1. Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.

2. *The Air Conditioning, Heating and Refrigeration News HVAC/R Source Guide.* Troy, MI: Business News Publishing Company, 1995.

3. Wantiez, Gary W. *ACR Electrical Components and Systems.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.

4. Smreker, Eugene and King Calvert. *Major Appliance Repair.* Stillwater, OK: The Mid- America Vocational Curriculum Consortium, 1987.

Suggested Activities

Suggested Supplemental Resources

The Mini-Notebook series written by Forest Nimms III and published by Radio Shack is a good and inexpensive source of basic electrical and electronic information. Nimm's *Engineer's Mini-Notebook Formulas, Tables, and Basic Circuits* is a good complement to materials in this text and to the general understanding of circuitry. The popularilty of the text speaks for itself; in 1994, it went into its fourth printing. *Formulas, Tables, and Basic Circuits* is just one in the Nimm's electronic series that you should find at a local Radio Shack store.

Two important websites for ACR students and instructors are:
http://www.hvaconline.com and **http://www.environ.com/hvacmall.htm**.

Both of these sites permit you to input questions about ACR service and receive answers from professionals in every area from installation to all kinds of troubleshooting.

These sites can also be used to access news from professional HVAC organizations, some of which are listed here:
Air Conditioning and Refrigeration Institute—**http://www.ari.org**
Air Conditioning Contractors of America—**http://www.acca.org**
American Society of Heating, Refrigerating, and Air Conditioning Engineers—
http://www.ashrae.org

Suggested Activities

Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Option A

4—Can perform job with no additional training.
3—Moderately skilled—Has performed job during training program; limited additional training may be required.
2—Limited skill—Has performed job during training program; additional training is required to develop skill.
1—Unskilled—Is familiar with process but is unable to perform job.

Option B

Yes—Can perform job with no additional training.
No—Is unable to perform job.

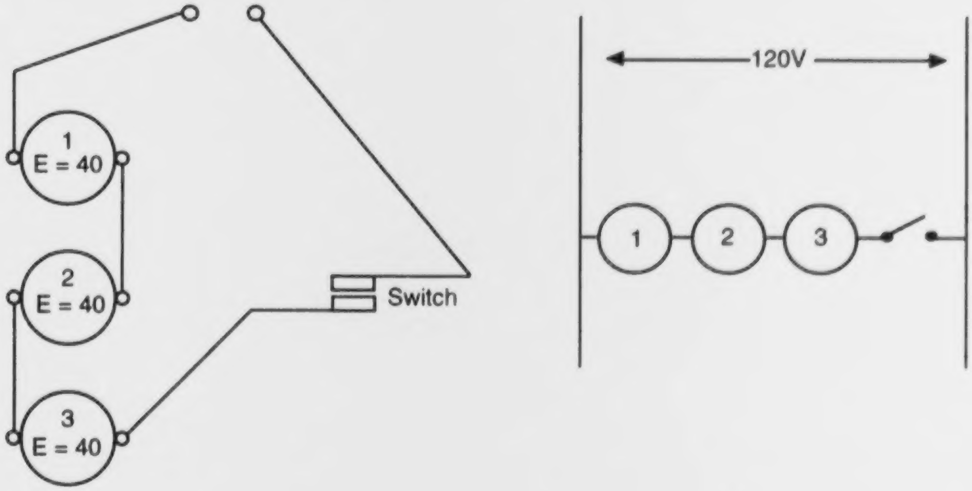
Circuits, Symbols, and Diagrams
Unit 4

Answers to Job Sheet Problems

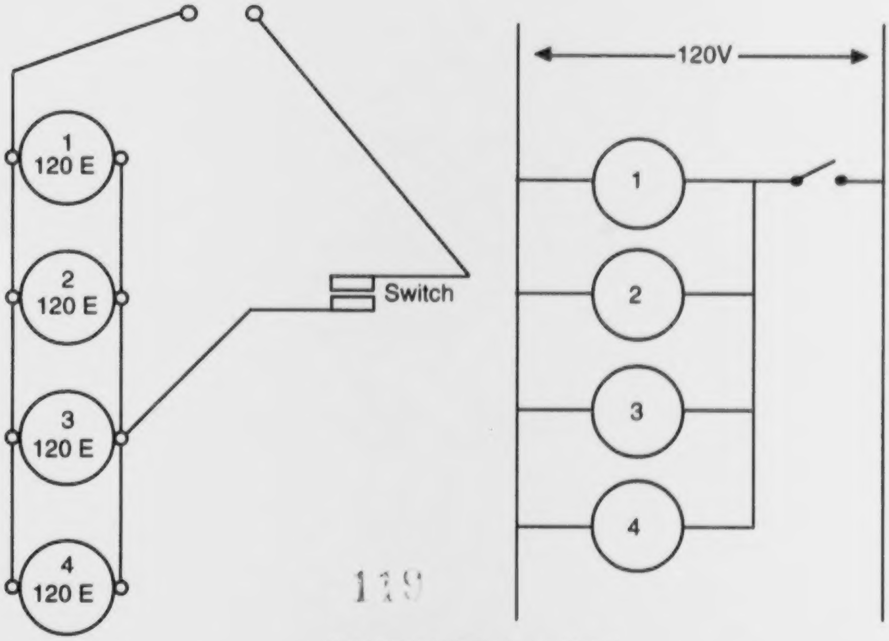
Job Sheet 1

Note: Correct alternative answers for the problems are acceptable, but the working model and schematic must match the pictorial.

A.


1
E = 40
2
E = 40
3
E = 40
Switch
120V
1
2
3

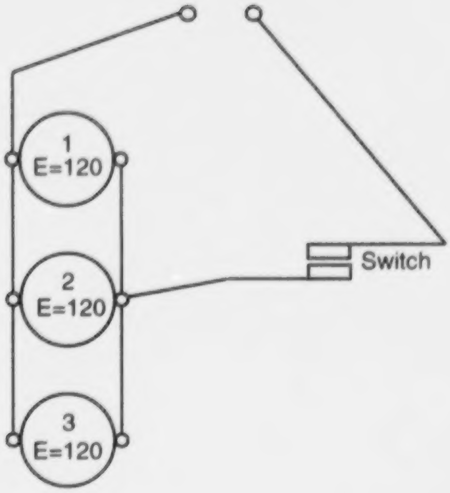
B.


1
120 E
2
120 E
3
120 E
4
120 E
Switch
120V
1
2
3
4

Answers to Job Sheet Problems

Job Sheet 1

C.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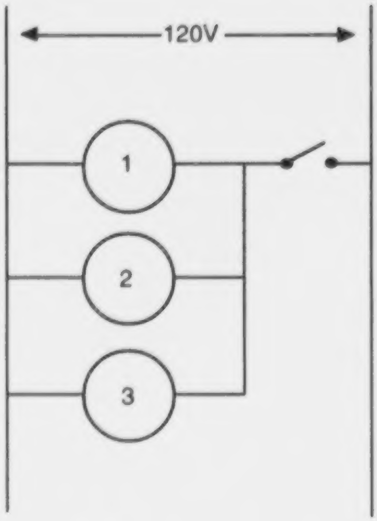
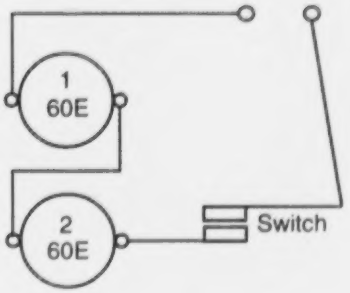
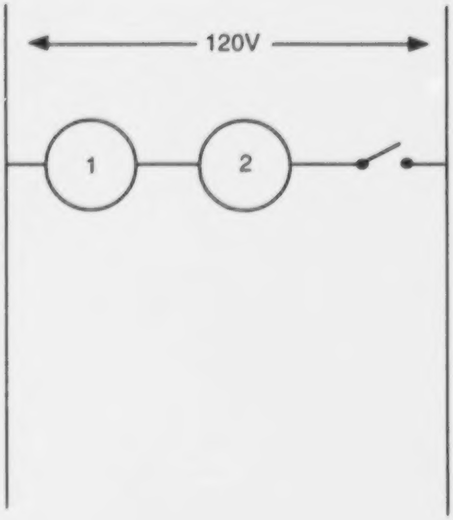
E=120
2
E=120
3
E=120
Switch



D.

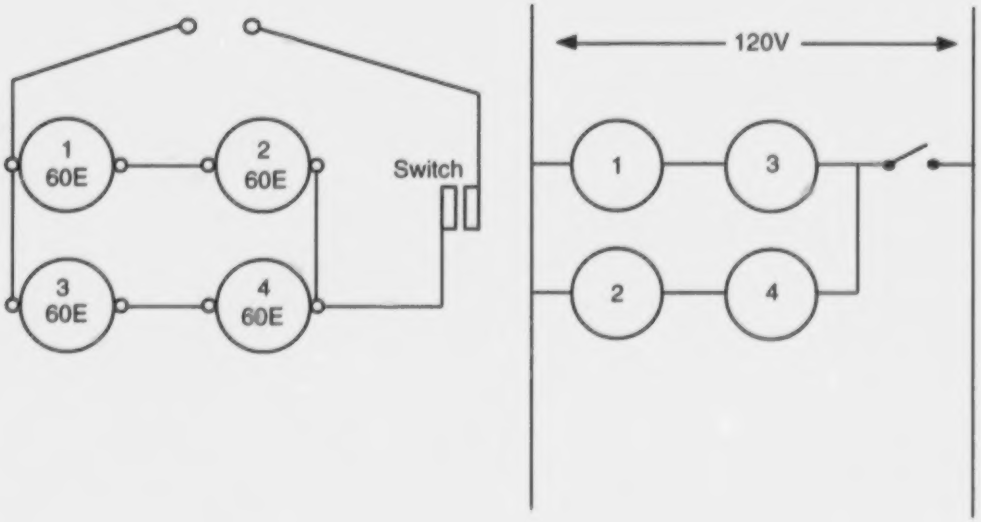

1
60E
2
60E
Switch



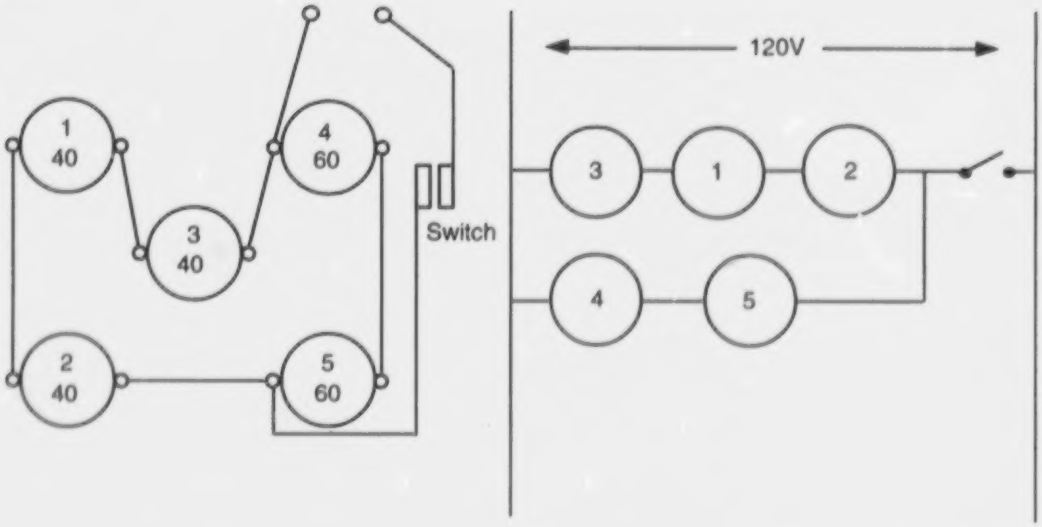
Answers to Job Sheet Problems

Job Sheet 2

A.


1
60E
2
60E
3
60E
4
60E
Switch
120V
1
3
2
4

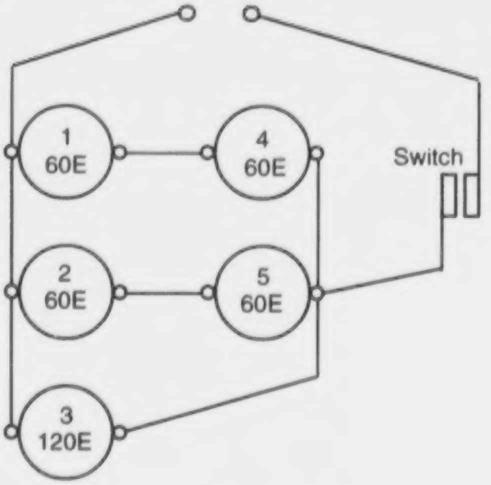
B.

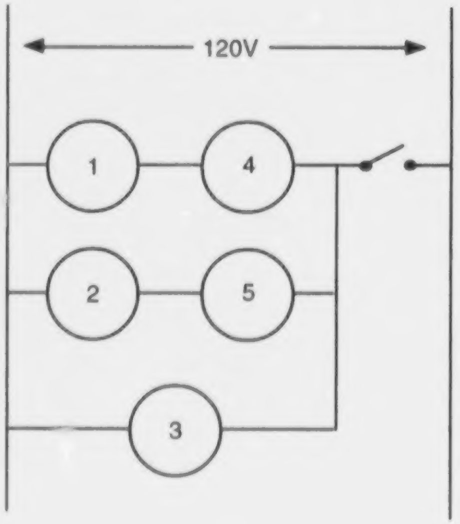

1
40
4
60
3
40
2
40
5
60
Switch
120V
3
1
2
4
5

Answers to Job Sheet Problems

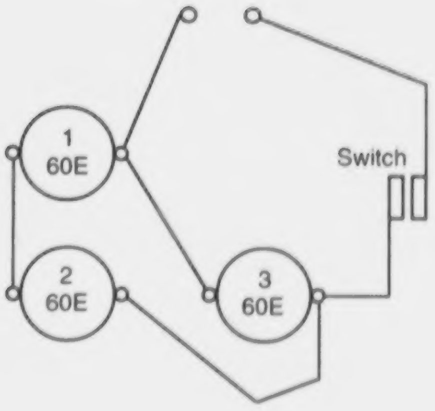
Job Sheet 2

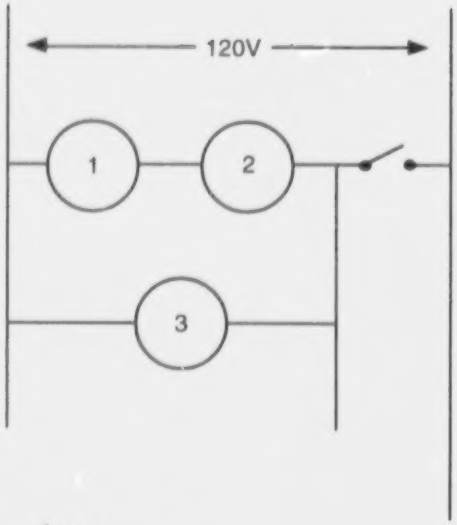
C.


1
60E
4
60E
Switch
2
60E
5
60E
3
120E



D.

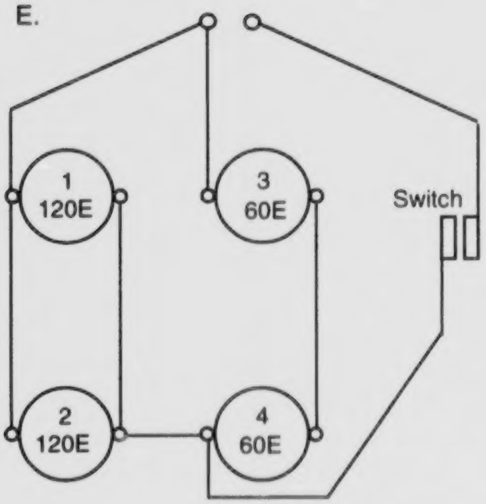

1
60E
Switch
2
60E
3
60E

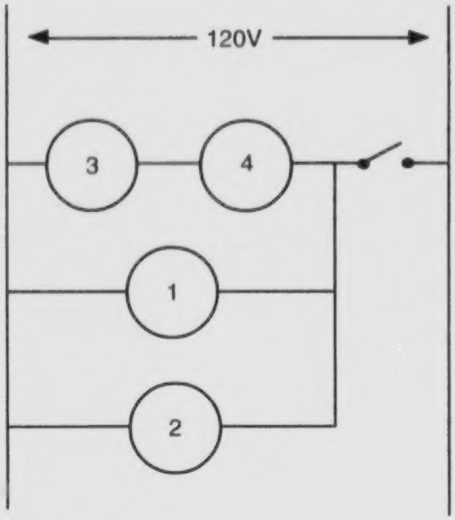


Answers to Job Sheet Problems

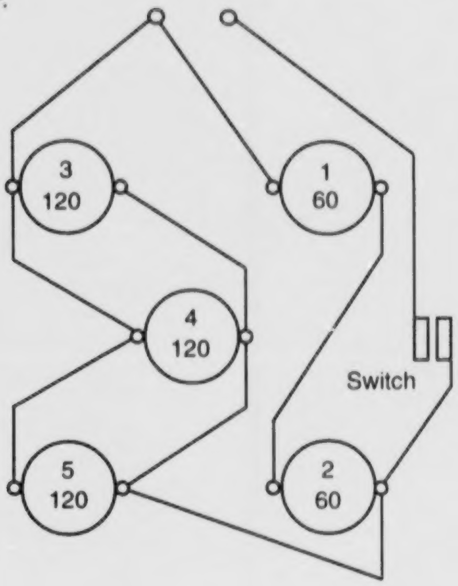
Job Sheet 2

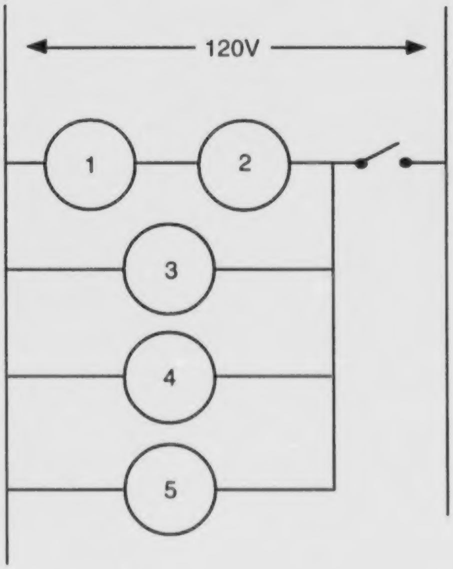
E.


1
120E
3
60E
Switch
2
120E
4
60E



F.

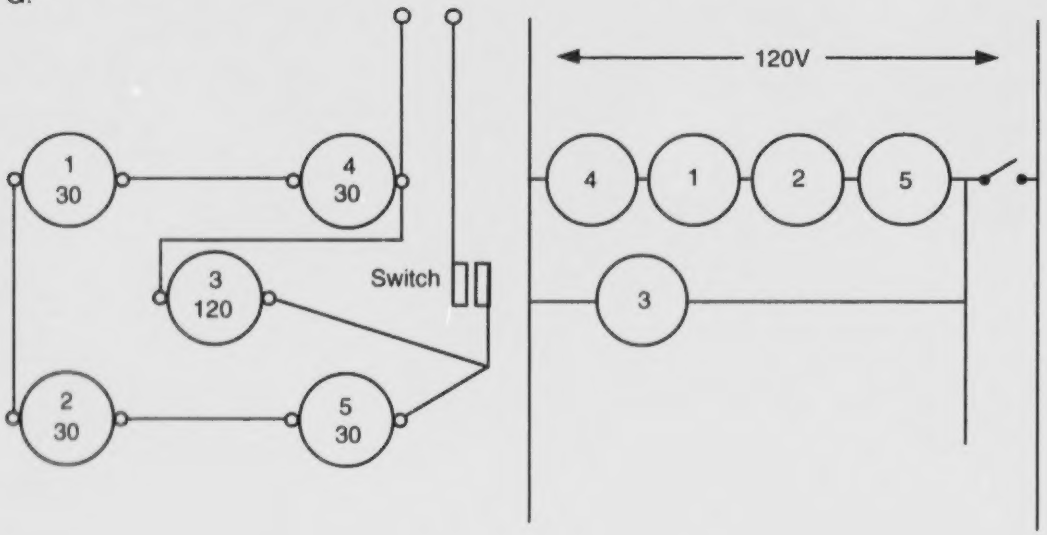

3
120
1
60
4
120
Switch
5
120
2
60



Answers to Job Sheet Problems

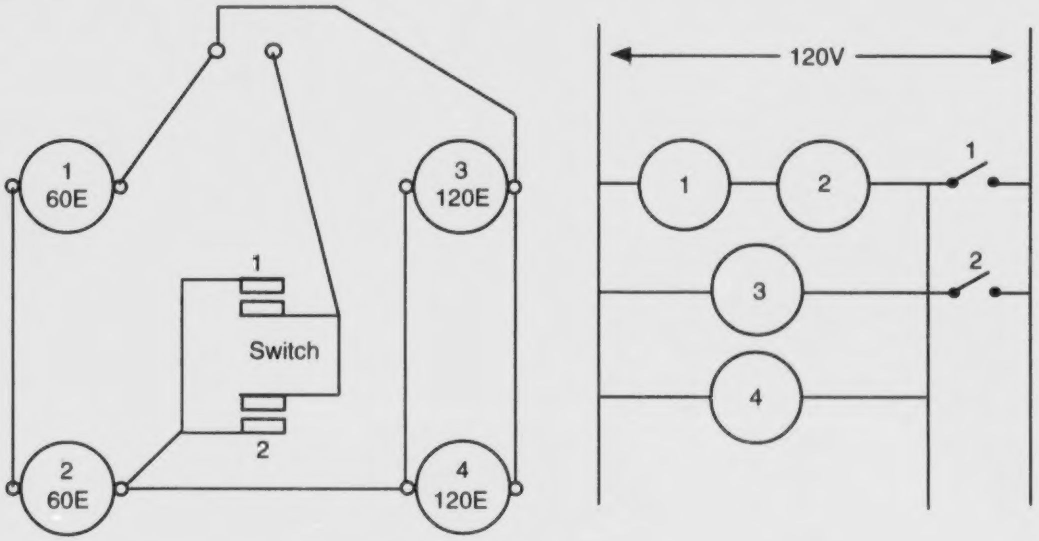
Job Sheet 2

G.


1
30
4
30
3
120
Switch
2
30
5
30
120V
4
1
2
5
3

Job Sheet 3

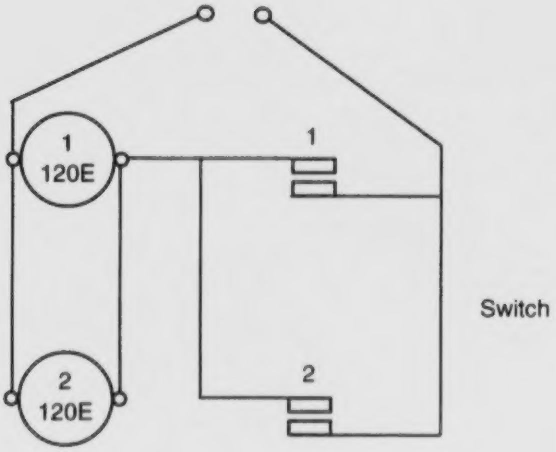
A.

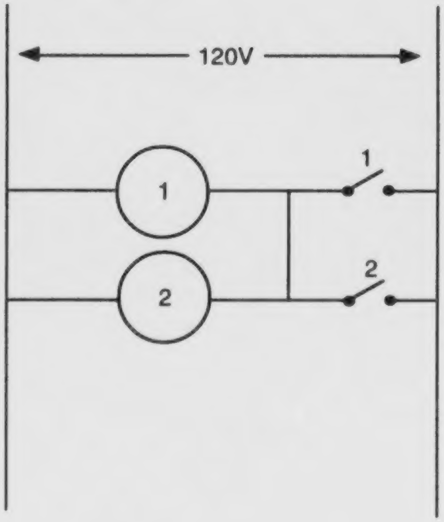

1
60E
3
120E
1
Switch
2
2
60E
4
120E
120V
1
2
1
3
2
4

Answers to Job Sheet Problems

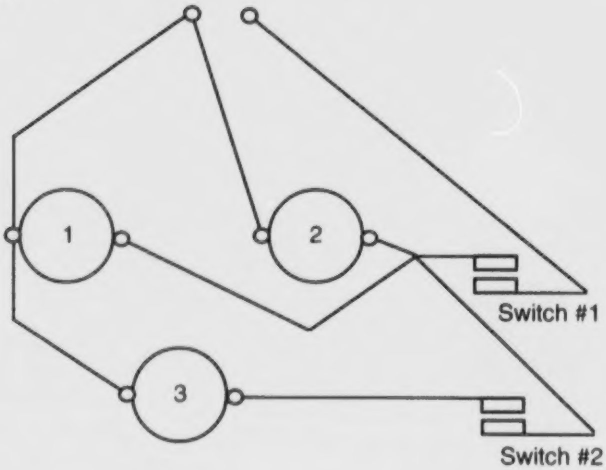
Job Sheet 3

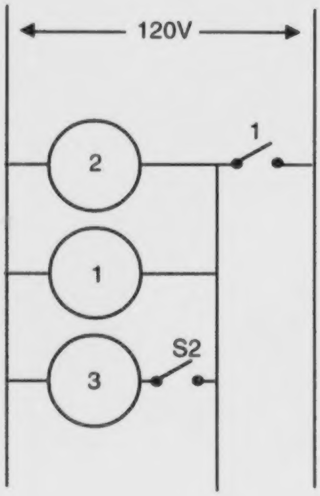
B.


1
120E
2
120E
1
2
Switch



C.

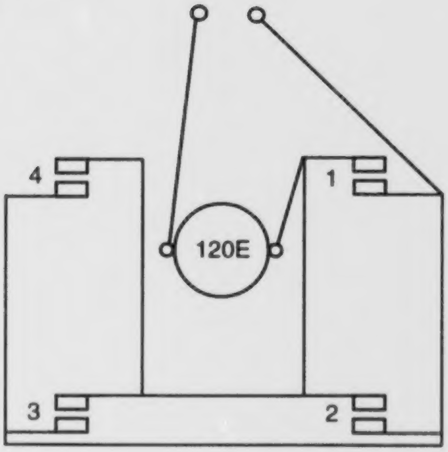

1
2
3
Switch #1
Switch #2

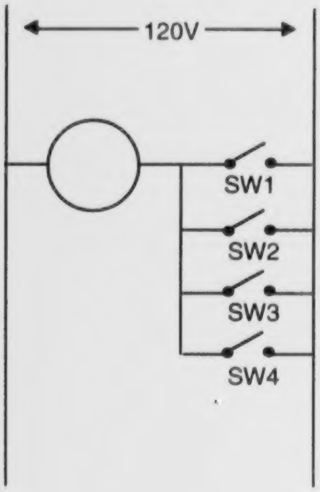

120V
2
1
1
3
S2

Answers to Job Sheet Problems

Job Sheet 3

D.




120V
SW1
SW2
SW3
SW4

Circuits, Symbols, and Diagrams
Unit 4

Answers to Written Test

1. a. 4
   b. 5
   c. 2
   d. 9
   e. 8
   f. 1
   g. 3
   h. 10
   i. 6
   j. 7

2. a. electronic
   b. precise
   c. 24
   d. 5
   e. PC
   f. soldered
   g. black, black
   h. input, output

3. a, b, c, e

4. a. (2) b. (3)

5. b, d, e, f

6. a. approximate
   b. field, color coding
   c. circuits
   d. component
   e. circuit

7. a. function
   b. order
   c. ladder
   d. circuit
   e. pictorial

8. a, c

9. a. approximate
   b. operate
   c. crossings
   d. two, one, long, short
   e. too close, too close

10. a. power
    b. rung
    c. circuit
    d. connect
    e. arrows
    f. number
    g. legends

11. a. (2) b. (1)

Circuits, Symbols, and Diagrams
Unit 4

Written Test

Name ______________________________ Date __________ Score _______

1. Match each term on the right with its correct definition.

__ a. The use of colored insulation around conductor wires to identify different wires or circuits and the marking of terminals with appropriate colors to ensure connections are matched and to facilitate more efficient troubleshooting

__ b. Wiring installed at a factory

__ c. Wiring installed in the field on a job site during installation or service

__ d. A wiring diagram designed specifically to assist the installing electrician in connecting power to the equipment, but does not show internal wiring

__ e. A schematic diagram which resembles a ladder; the legs or siderails of the ladder being the power supply and the individual parallel circuits forming the rungs of the ladder

__ f. Descriptive list of the components in a wiring diagram

__ g. A wiring diagram which shows pictures or representative drawings of electrical components in their approximate location in the equipment

__ h. A wiring diagram which shows electrical components as symbols, how they function, and their order of operation

__ i. A drawing which represents a specific electrical or electronic component and its function

__ j. A drawing of the electrical and/or electronic circuits within a piece of equipment or between pieces of equipment

1. Legend
2. Field wiring
3. Pictorial diagram
4. Color coding
5. Factory wiring
6. Symbol
7. Wiring diagram
8. Ladder schematic diagram
9. Installation diagram
10. Schematic diagram

Written Test

2. Complete statements about electronic circuits. Write in the information that best completes each of the following statements.

   a. Electrical and electromechanical control circuits and devices are gradually being replaced by ____________________ devices and circuits.

   b. Electronic circuits are less expensive, more reliable, and provide more ________________ control.

   c. Electrical circuits use AC voltages commonly ranging from _____V to hundreds of volts, and amperages ranging from a few tenths of an amp to tens of amps.

   d. Electronic circuits use DC voltages commonly ranging from ___V to 15V, and amperages measured in milliamps, thousandths of an amp, or even microamps, millionths of an amp.

   e. Most electronic circuits in the ACR field are mounted on printed circuit boards commonly called ________ boards.

   f. The desired circuit is laid out with copper foil on the back of the PC board and components such as resistors, capacitors, and relays are mounted on top of the PC board and ____________________ to the foil circuit.

   g. Some electronic circuits are PC boards and other components packaged in sealed modules commonly known as ________________ boxes, although they are not always ______________.

   h. Regardless of size, PC boards and modules are usually serviced by simply checking ________________ and ________________ voltages and replacing the entire board or module if any part of it has failed.

3. Select true statements about integrated circuits. Place an "X" beside each statement that is true.

   __ a. Integrated circuits commonly called chips or integrated circuit chips, or ICs, are often mounted on PC boards used as control boards in ACR systems.

   __ b. A chip is a tiny wafer of semiconductor material containing microminiature, self-contained circuits designed to perform specific functions.

   __ c. The use of semiconductors in solid-state devices to make microminiature integrated circuits has made it possible for them to perform the same functions that used to require a room full of electronic equipment.

Written Test

__ d. The semiconductor device most responsible for this miniaturization is the resistor, consisting of a wafer of semiconductor material sandwiched between two layers of a different semiconductor material.

__ e. More complex integrated circuits called microprocessors are programmed to make decisions and perform complex tasks and are used in such devices as personal computers or electronic comfort system control centers.

4. Complete statements about the language of electricity. Circle the number in front of the information that best completes each of the following statements.

   a. The use of symbols and wiring diagrams reduces long descriptions of electrical actions of ACR equipment to:

      (1) a form of coded communication.
      (2) a kind of shorthand.
      (3) a form of arithmetic.

   b. A single electrical symbol in a wiring diagram can tell a service technician such things as:

      (1) where the component was made.
      (2) how much the component costs.
      (3) whether the component is a source, load, path, or switch.

5. Select true statements about sources and applications of wiring diagrams. Place an "X" beside each true statement.

__ a. When an ACR manufacturer builds equipment, pictorial and schematic diagrams are usually available in the form of working plans available from a local wholesaler.

__ b. An installation diagram showing the proper electrical hookup to the equipment will also be packaged with the equipment.

__ c. After the installer sets the equipment in place, the electrician will use the schematic diagrams to connect source power to the unit.

__ d. A service technician will find the pictorial and schematic diagrams invaluable when starting the equipment initially or troubleshooting the equipment.

__ e. A service technician may need to sketch a rough version of a pictorial or schematic diagram if internal wiring has been altered or diagrams are missing.

__ f. A service technician may need to sketch a control diagram or connecting diagram to show how controls in system components are connected.

Written Test

6. Complete statements about pictorial wiring diagrams. Write in the information that best completes each of the following statements.

   a. Pictorial diagrams show system components as representative drawings or detailed reproductions, and show them in their ____________________ location.

   b. Pictorial diagrams provide a good guide to ______________ wiring because they show the components physical relation to one another and the ______________ ________________ of the wires connecting them.

   c. Because pictorial diagrams are designed to show physical relationships, _________________ can be difficult to trace on a pictorial.

   d. A good pictorial diagram will show, in some way, every wire, terminal, connector, and ____________________ in a piece of equipment.

   e. Pictorial diagrams help a service technician troubleshoot components and trackdown connections, but tracing an entire __________________ can be difficult on a pictorial.

7. Complete statements about schematic wiring diagrams. Write in the word(s) or information that best completes each of the following statements.

   a. Schematic wiring diagrams show system components as symbols which show the ___________________ of the component.

   b. Schematic diagrams show the _________________ of operation of components rather than their location.

   c. The most common type of schematic wiring diagram is the ___________________ diagram.

   d. Schematic diagrams make circuit troubleshooting easy because the service technician can usually see at a glance which components are in each _________________, and their order of operation.

   e. Because schematic diagrams do not show actual details of wires, terminals, and connectors, they are difficult to use for wire by wire troubleshooting, but are effective when used in conjunction with a ___________________________.

Written Test

8. Select true statements about electronic wiring diagrams. Place an "X" beside each true statement.

    __a. A special type of schematic wiring diagram is used to show electronic components.

    __b. This diagram is not similar in any way to a ladder diagram.

    __c. The use of semicinductors in electronic circuitry make it difficult to trace an individual circuit because the routing of the circuit varies with changes in voltage or other conditions such as temperature, light, or pressure.

9. Complete statements about drawing a pictorial diagram. Write in the word(s) or information that best completes each of the following statements.

    a. Draw representative drawings of the components in their ____________________ locations or their relationships to each other.

    b. Draw lines to represent the wires connecting the components in such a way as to make the components ________________________ as desired.

    c. Avoid wire __________________whenever possible.

    d. Avoid using ________ wires where _________ wire would do, and avoid using _____________ wires where ___________wires would do.

    e. Avoid drawing wires _____ ___________to each other or ______ ________ to components.

10. Complete statements about building a ladder schematic diagram. Write in the word(s) or information that best completes each of the following statements.

    a. Locate and identify the power source on the pictorial diagram, and draw vertical lines or the "legs" of the ladder to represent the ________________ source or sources.

    b. Identify the load or loads in the pictorial diagram and draw them between the legs so that each load will be located on a separate ________________of the ladder.

    c. Identify the control or controls for each ___________________ in the pictorial, and draw the appropriate symbol so that it will be located on the same rung as the load it controls.

Written Test

d. Connect the components along the rungs with horizontal lines that ____________________ to the legs.

e. Label the source with the amount of voltage, and use____________________ to identify the legs of the source voltage.

f. If symbols do not identify components or there are more components than one using the same symbol, the symbol must be labeled with a ____________________, abbreviation, or other designation.

g. Pictorials and schematics are often accompanied by ________________ to provide a key for properly interpreting labels and special entries by the OEM.

11. Solve problems about using symbols. Circle the number in front of the information that best solves each of the following problems.

a. A service technician has a ladder schematic and a pictorial for the same piece of equipment, but the symbols on the ladder schematic don't match the symbols on the pictorial, and the technician thinks the manufacturer sent the wrong schematic. To solve the problem:

(1) take time to call the manufacturer and report the error and get a new schematic.
(2) the schematic is supposed to have symbols different from those on the pictorial; the technician needs to learn schematic symbols.

b. A coworker talking about the difference between pictorials and schematics says that only schematics should be used on the job site. To solve the problem:

(1) remind your coworker that either pictorials or schematics, or both, can be used because pictorials show location and appearance of components and schematics show function and operation of components.

(2) remind your coworker that the most effective drawing to use on the job site is the installation drawing.

Permission to duplicate this test is granted.

Circuits, Symbols, and Diagrams
Unit 4

Unit Evaluation Form

Student Name ______________________ Date ________ Unit Rating _____

Job Sheet 1—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Basic Series and Parallel Circuits — Rating ________

Comments:

Job Sheet 2—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Series-Parallel Circuits — Rating ________

Comments:

Job Sheet 3—Draw Pictorials, Fabricte Working Models, and Draw Ladder Schematics for Circuits With Varied Loads and Switching — Rating ________

Comments:

Other:

Written Tests ____________ Pretest ____________ Posttest ____________

Total ____________

Teacher Signature Date ____________

Student Signature Date ____________

Permission to duplicate this form is granted.

Controls and Protection Devices
Unit 5

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan enrichment of exceptional students as well as accommodation of special needs students.
4. Add overheads or other graphic materials as desired to enhance instruction.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss and demonstrate the procedures in the job sheets. Review criteria for evaluating these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of written test. Add or modify test items as needed.
13. Give written test.

Suggested Activities

14. Compile job sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets added to the unit.

15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: ASCANS Report for America 2000.* These SCANS skills and competencies have been adapted by MAVCC to help instructors and program planners effectively articulate curriculum.

1. Locate controls or have available equipment to demonstrate the types of controls discussed in Objectives 1 and 2. Relate controls to the types of systems where they are used. **Basic skills, listening and reading.**

2. Have an assortment of protection devices available when students discuss Objectives 8 and 9. Point out how these devices are designed for specific applications and how some are designed so that they cannot be misapplied. **Basic skills, science, reading, and listening.**

3. Have individual students check their own homes or apartments for control and protection devices and then report their findings to the class. To enrich the report, have each student present the symbols for the types of switches or devices they have found so students can work with the symbols from Objectives 5 and 6. **Basic skills, speaking.**

4. Prepare the appropriate trainers or equipment for students to use when they build and test working models of the circuits presented in the job sheets. Impress students with the importance of understanding shunt circuits both simple and complex. **Basic skills, listening and science.**

5. Stress electrical safety throughout this unit. Have students talk about some of the safety measures they should employ when making the working models of the circuits presented in the job sheets. **Basic skills, listening.**

Suggested Activities

Resources Used in Developing This Unit

1. Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.
2. *The Air Conditioning, Heating and Refrigeration News HVAC/R Source Guide.* Troy, MI: Business News Publishing Company, 1995.
3. Wantiez, Gary W. *ACR Electrical Components and Systems.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.
4. Smreker, Eugene and King Calvert. *Major Appliance Repair.* Stillwater, OK: The Mid- America Vocational Curriculum Consortium, 1987.

Suggested Supplemental Resources

Analyzing control circuits is a major topic in Honeywell's *Fundamentals of Residential Controls.* This inexpensive ($9.00) text is an excellent training supplement for both beginning and advanced HVACR students. The book is one of Honeywell's programmed instruction series presented in an easy step-by-step, question-answer format. Other topics in the text include: nature of electricity; rules governing electricity; inductive and capacitive circuits;principles of motor operation; power, transformer principles; and relay principles. The Honeywell product number for this impressive 250-page workbook is 71-97083. See your local Honeywell distributor or call 1-800-345-6770 ext.2040. You may also access the Honeywell website at **http://www.honeywell.com/controls.html**.

Other beneficial websites for ACR students and instructors are: **http://www.hvaconline.com** and **http://www.environ.com/hvacmall.html**. With certain membership requirements, both of these sites permit you to input questions about ACR service and receive answers from professionals in every area from installation to all kinds of troubleshooting.

These sites can also be used to access news from professional HVAC organizations, some of which are listed here:

Air Conditioning and Refrigeration Institute—**http://www.ari.org**
Air Conditioning Contractors of America—**http://www.acca.org**
American Society of Heating, Refrigerating, and Air Conditioning Engineers—**http://www.ashrae.org**

Suggested Activities

Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Option A

4—Can perform job with no additional training.
3—Moderately skilled; has performed job during training program, but limited additional training may be required.
2—Limited skill; has performed job during training program, but additional training is required to develop skill.
1—Unskilled; familiar with process but is unable to perform job.

Option B

Yes—Can perform job with no additional training.
No—Is unable to perform job.

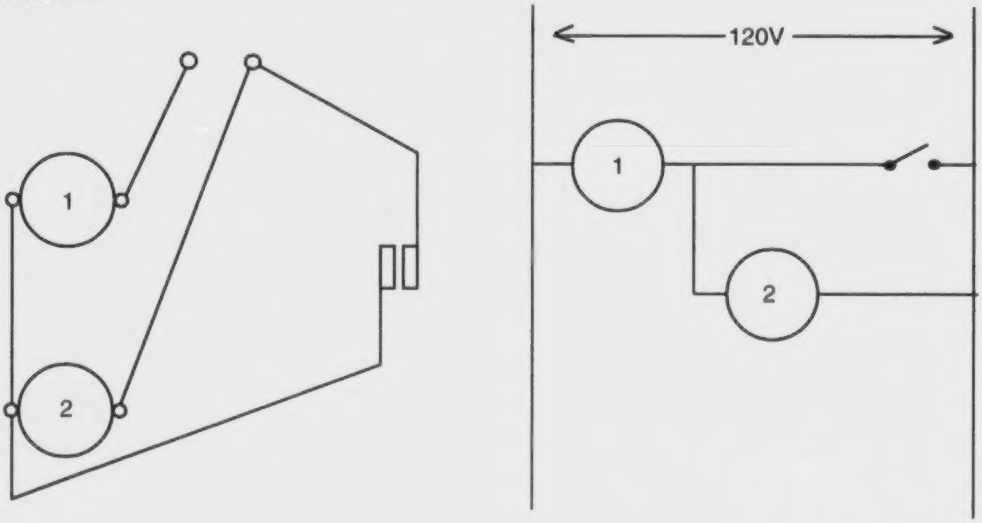
Controls and Protection Devices
Unit 5

Answers to Job Sheet Problems

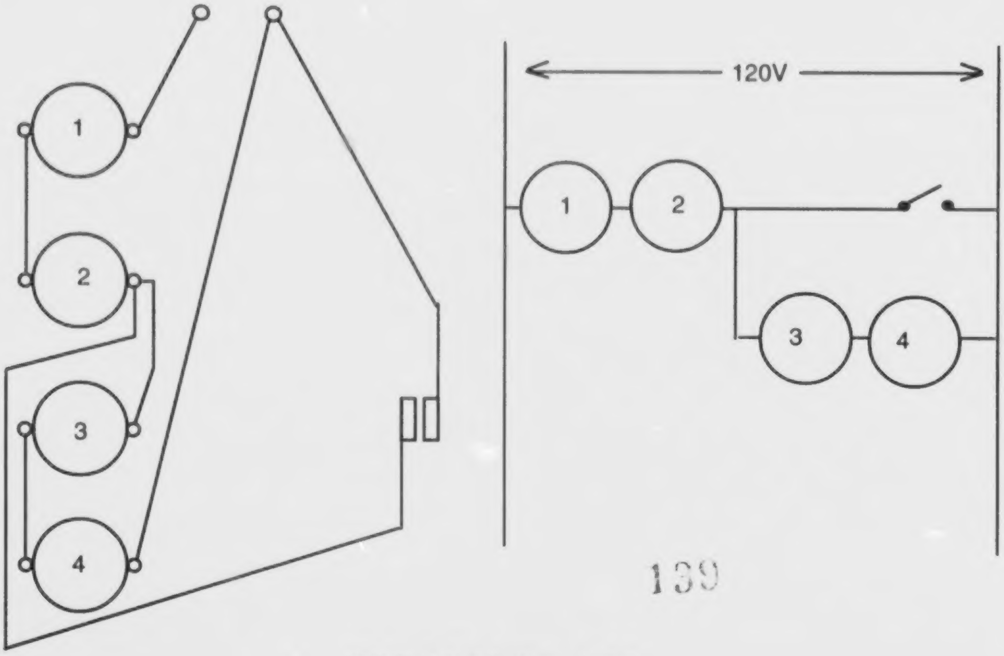
Job Sheet 1

Note: Drawings may vary, but circuits must meet specifications and schematics must match the pictorials.

A.



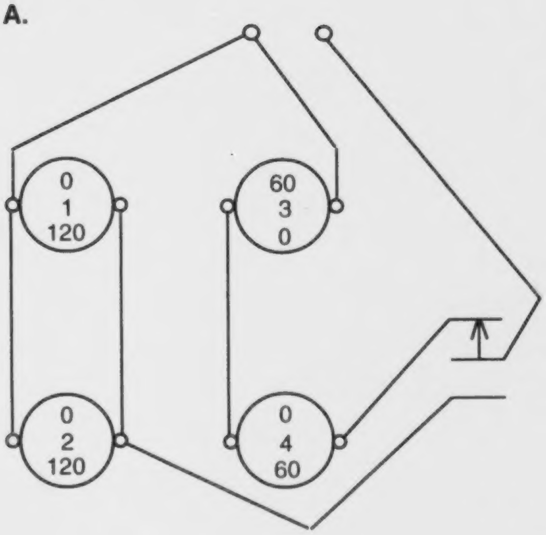
B.

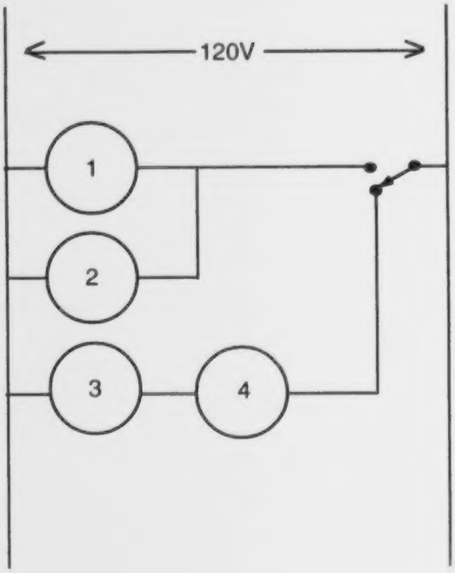


Answers to Job Sheet Problems

Job Sheet 2

A.


0
1
120
60
3
0
0
2
120
0
4
60



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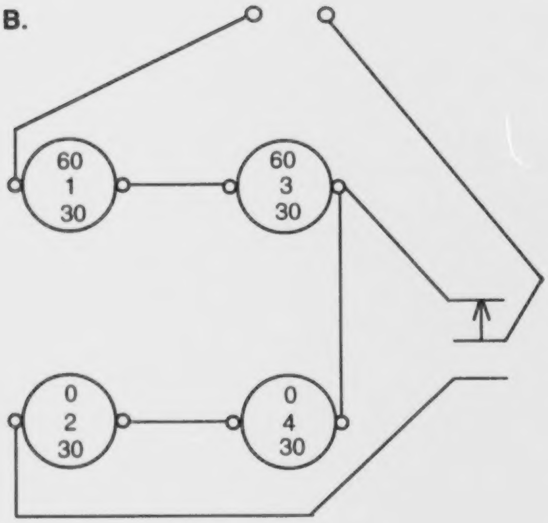
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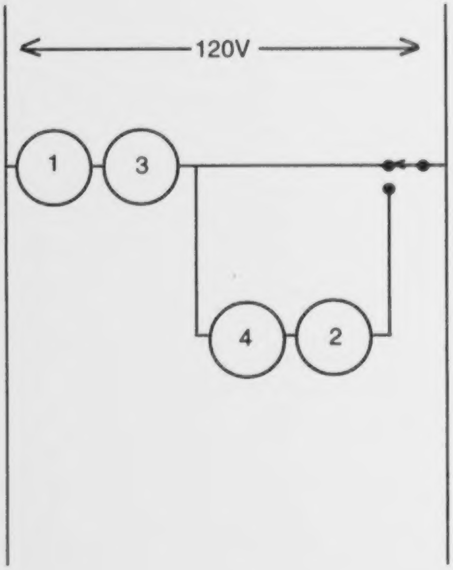
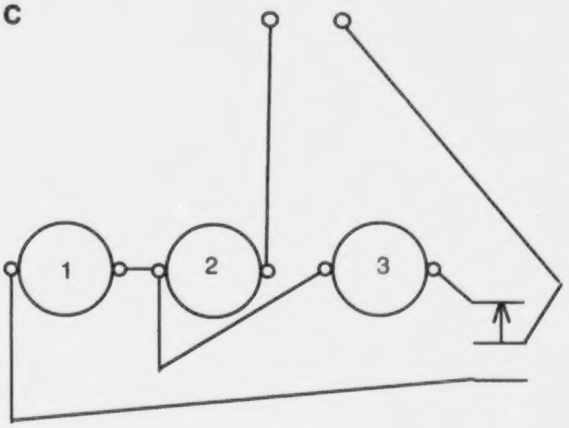
1
30
60
3
30
0
2
30
0
4
30

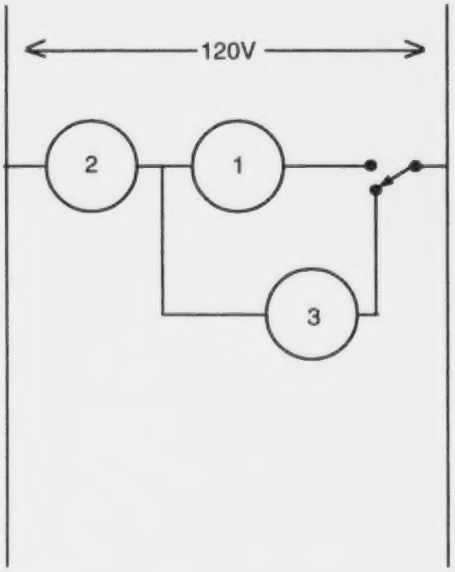


Answers to Job Sheet Problems

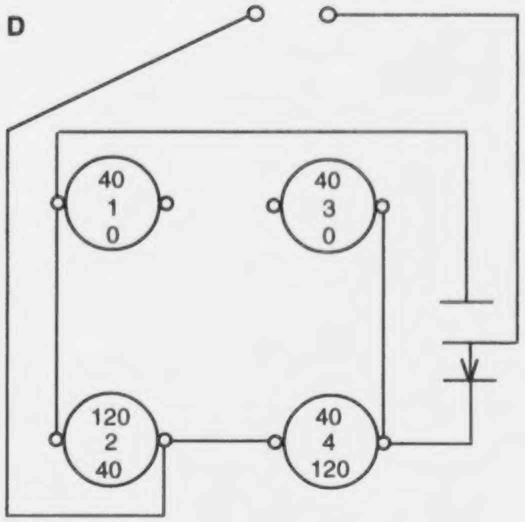
Job Sheet 2

C





D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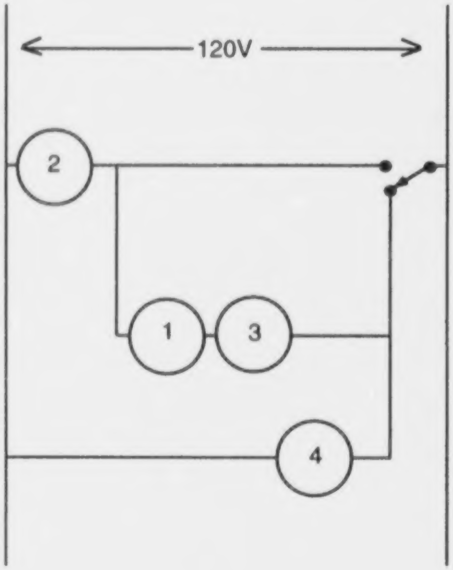
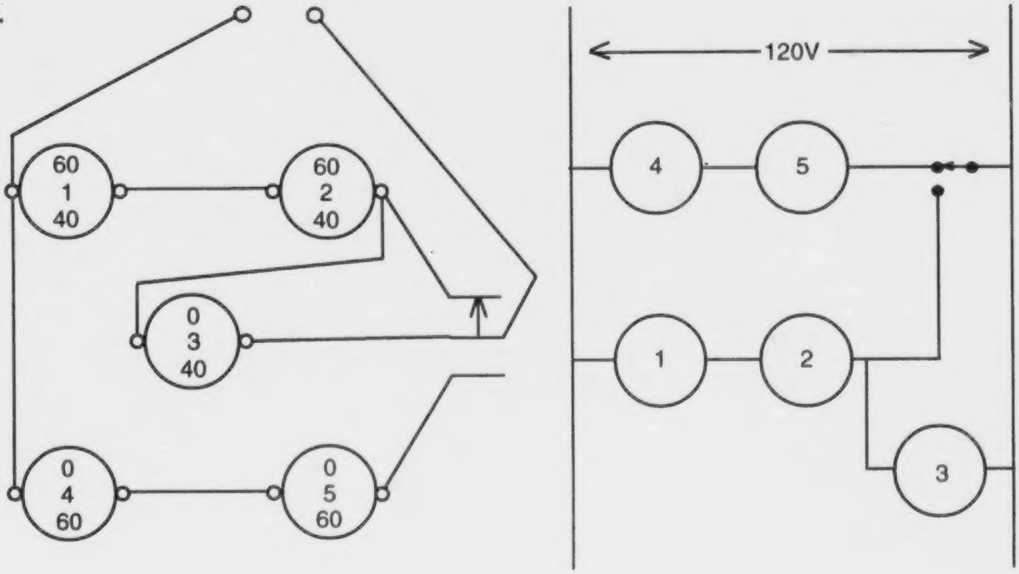
1
0
40
3
0
120
2
40
40
4
120



Answers to Job Sheet Problems

Job Sheet 2

E.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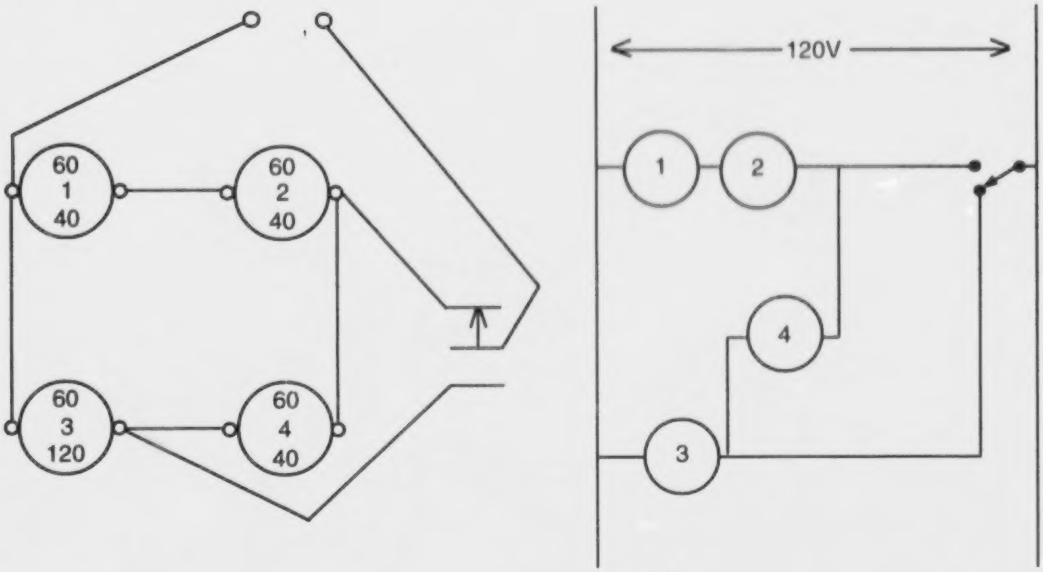
1
40
60
2
40
0
3
40
0
4
60
0
5
60
120V
4
5
1
2
3

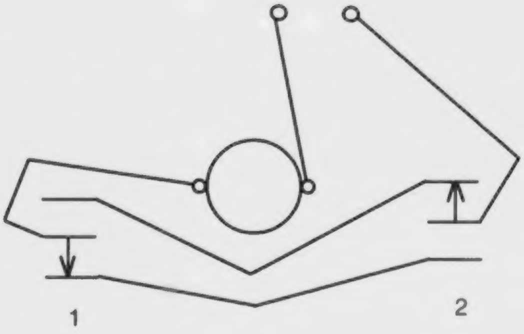
F.

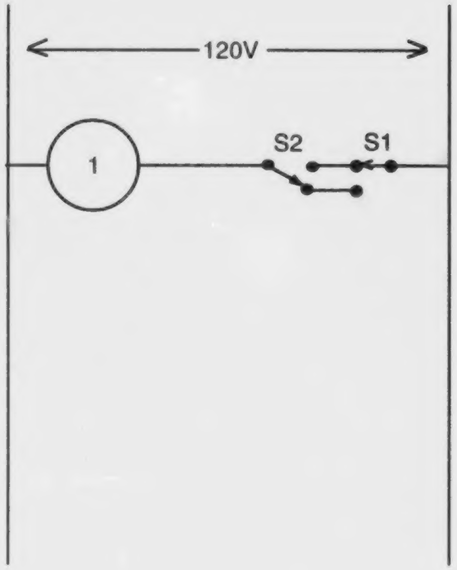

60
1
40
60
2
40
60
3
120
60
4
40
120V
1
2
4
3

Answers to Job Sheet Problems

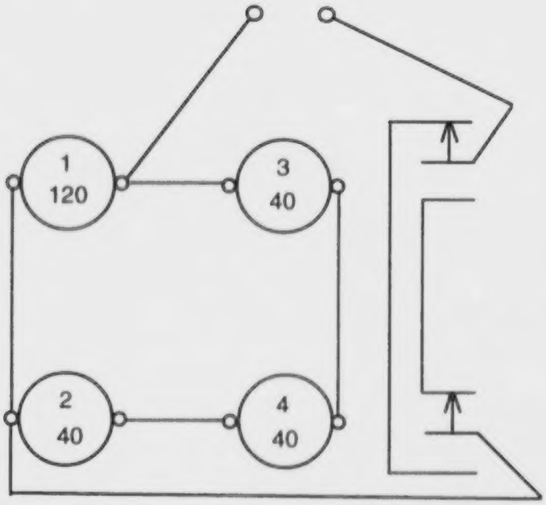
Job Sheet 2

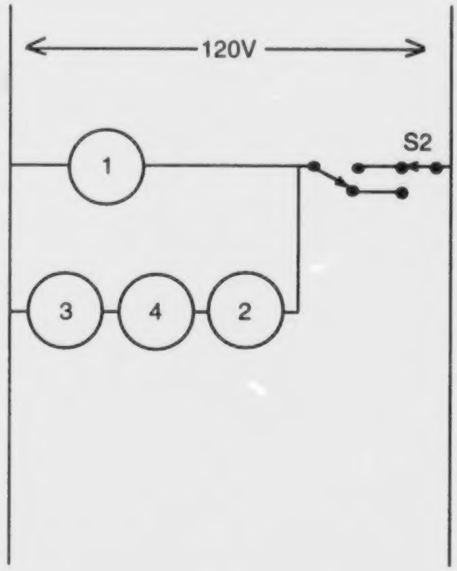
G.





H.

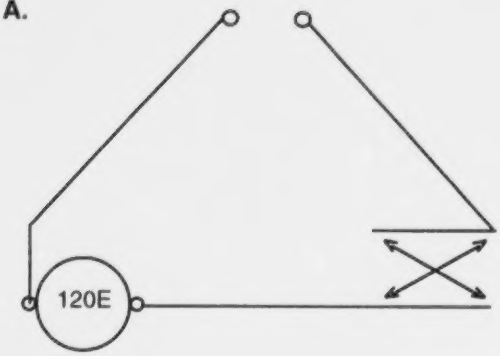

1
120
3
40
2
40
4
40

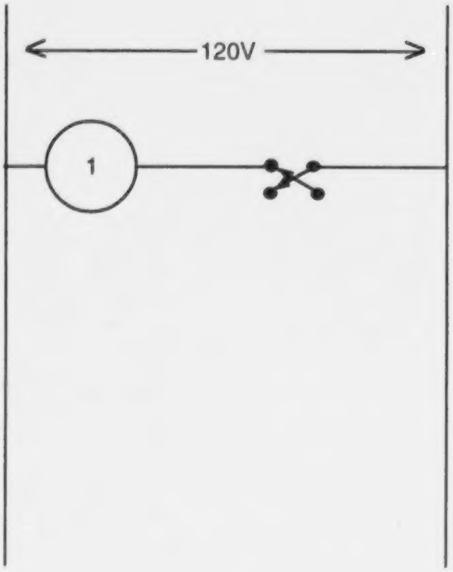

120V
1
S2
3
4
2

Answers to Job Sheet Problems

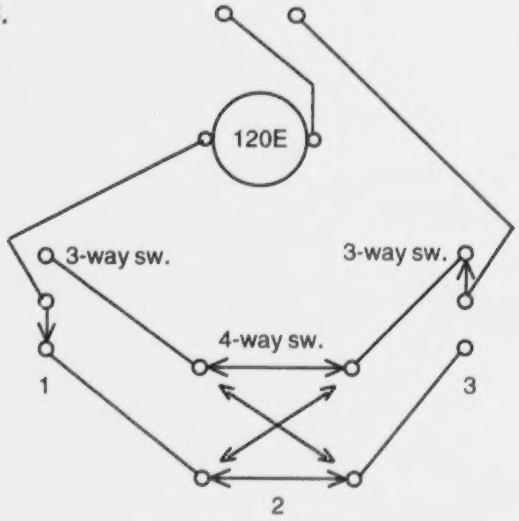
Job Sheet 3

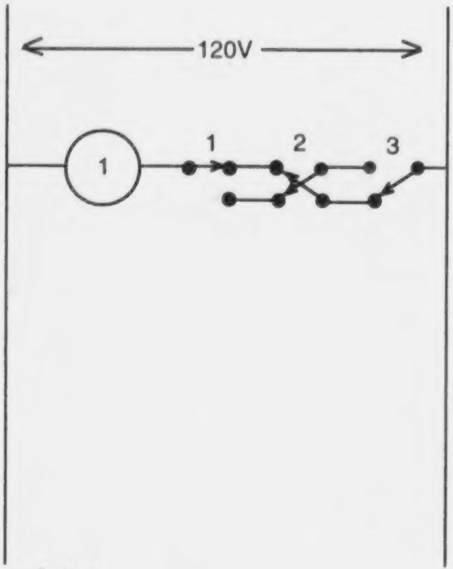
A.





B.

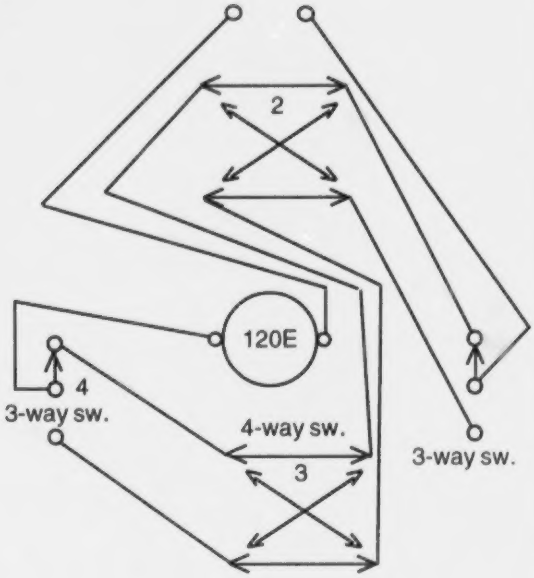

120E
3-way sw.
3-way sw.
4-way sw.
1
2
3

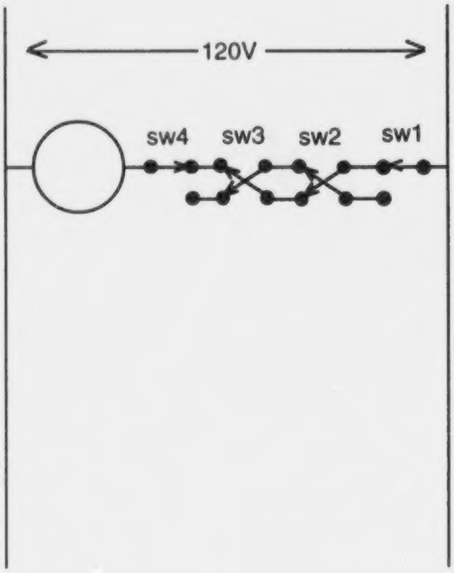


Answers to Job Sheet Problems

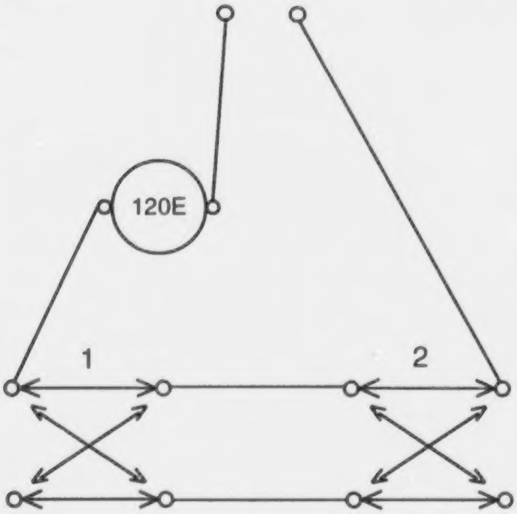
Job Sheet 3

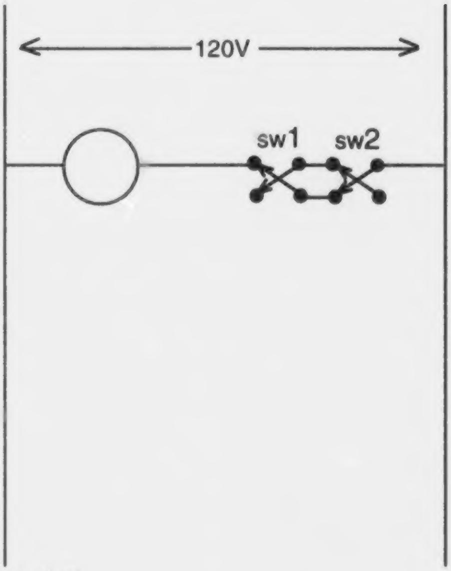
C.


2
120E
4
3-way sw.
4-way sw.
3
3-way sw.


120V
sw4
sw3
sw2
sw1

D.

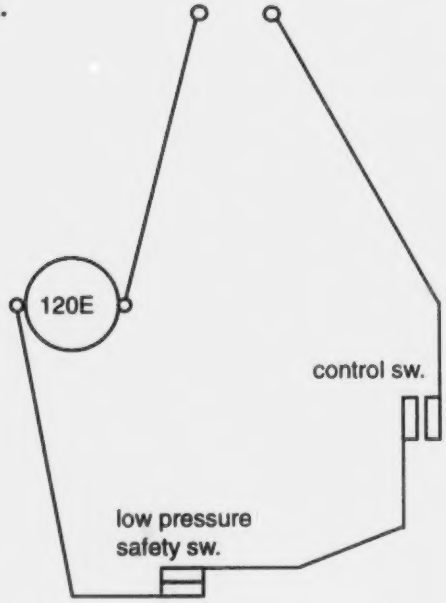


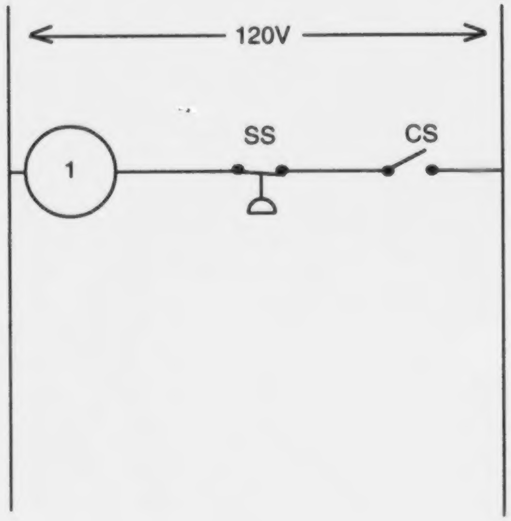

120V
sw1
sw2

Answers to Job Sheet Problems

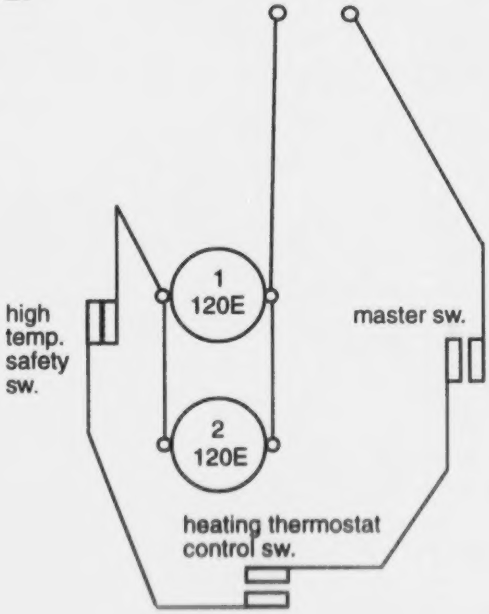
Job Sheet 4

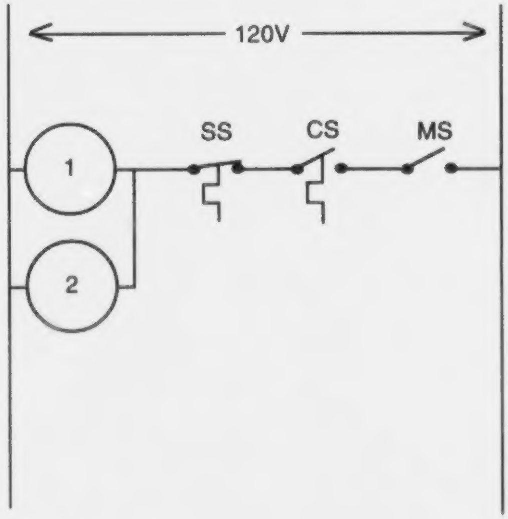
A.


120E
control sw.
low pressure
safety sw.



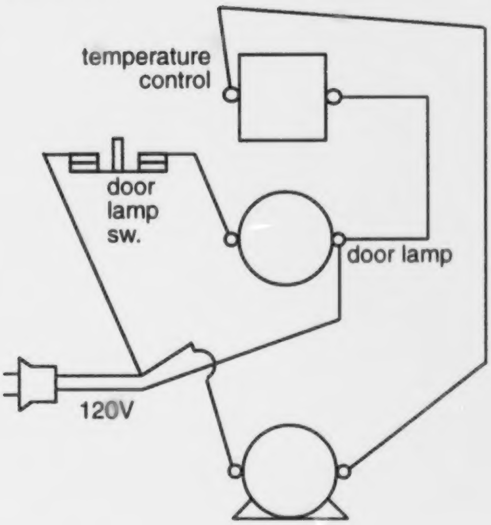
B.

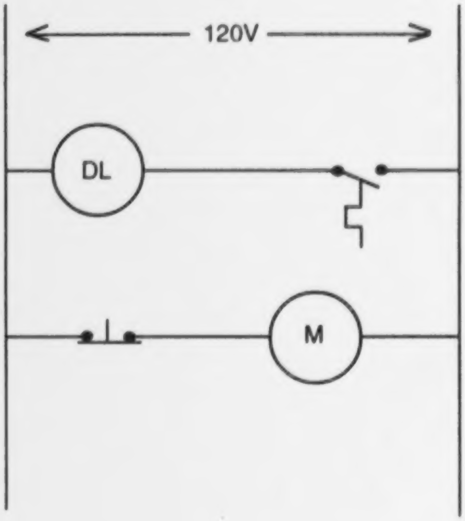

high
temp.
safety
sw.
1
120E
2
120E
master sw.
heating thermostat
control sw.


120V
1
2
SS
CS
MS

Answers to Job Sheet Problems

Job Sheet 5


temperature
control
door
lamp
sw.
door lamp
120V



Controls and Protection Devices
Unit 5

Answers to Written Test

1. a. 4
b. 8
c. 1
d. 7
e. 3
f. 10
g. 5
h. 9
i. 2
j. 6

2. a, e, f, g

3. a. (2)
b. (2)
c. (1)
d. (2)
e. (2)

4. a. (2)
b. (3)
c. (1)
d. (3)

5. a. points
b. touching
c. separated
d. brought together
e. separated
f. single, double
g. legs
h. positions
i. single

6. a. 4
b. 9
c. 1
d. 8
e. 5
f. 2
g. 6
h. 3
i. 7

Answers to Written Test

7. a. least
   b. resistance
   c. disconnected
   d. connected
   e. open, closed
   f. different
   g. ice maker
   h. Multiple

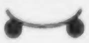
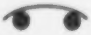
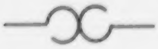
8. a, b, e, f, g

9. a, b

10. a. 4
   b. 6
   c. 2
   d. 7
   e. 5
   f. 3
   g. 1

11. a. (3)
   b. (4)
   c. (2)
   d. (2)

12. a, c

13. a. warp
   b. current
   c. contacts
   d. pilot
   e. automatic
   f. furnace
   g.  or 
   h. 

14. a. (1)
   b. (2)
   c. (1)
   d. (2)

Controls and Protection Devices
Unit 5

Written Test

Name ______________________________ Date _________ Score _________

1. Match each term on the right with its correct definition.

__ a. A control that resets itself after conditions that caused a circuit interruption have ceased

__ b. A resettable overcurrent protection device that resembles a switch

__ c. Any device that operates or regulates electrical and mechanical systems

__ d. A nonresettable overcurrent protection device which contains elements or an element which melts and opens a circuit at a specified amperage

__ e. A device that controls or interrupts a line voltage circuit

__ f. A control that must be reset manually after it has interrupted a circuit

__ g. A device in a circuit that limits the amperage to a specified amount

__ h. A device that controls or interrupts a control circuit

__ i. Any device that protects the equipment or circuit from excessive conditions that could damage equipment, harm people, or impair operation

__ j. Any device used to open and/or close an electrical circuit

1. Control
2. Protection device
3. Line duty control
4. Automatic reset protection device
5. Overcurrent protection
6. Switch
7. Fuse
8. Circuit breaker
9. Pilot duty control
10. Manual reset protection device

Written Test

2. Select true statements about controls and their applications. Place an "X" beside each true statement.

__ a. Almost all electrical and mechanical devices have some means for stopping and starting their operation.

__ b. The simplest control is a switch.

__ c. Most controls are mechanical.

__ d. Control devices are categorized as switches, relays, or transformers.

__ e. Primary controls respond to operating controls and cycle or operate the equipment or system which affects conditions.

__ f. Operating controls respond to conditions and cycle or operate primary controls.

__ g. Limit controls limit the maximum and/or minimum conditions under which equipment will operate.

3. Complete statements about types of controls. Circle the number in front of the information that best completes each of the following statements.

a. Thermostats are good examples of controls that respond to changes in:

(1) pressure.

(2) temperature.

(3) liguid or gas flow.

b. Condenser fan cycling controls are examples of controls that respond to changes in:

(1) time.

(2) pressure.

(3) liquid level.

c. Gas furnace vent fan safeties are examples of controls that respond to changes in:

(1) liquid or gas flow.

(2) liquid level.

(3) temperature.

Written Test

d. Sump pump float switches are examples of controls that respond to changes in:

   (1) time.
   (2) liquid level.
   (3) pressure.

e. Setback thermostats are examples of controls that respond to changes in:

   (1) pressure.
   (2) time.
   (3) temperature.

4. Complete statements about control systems. Circle the number in front of the information that best completes each of the following statements.

   a. The area in which temperature, pressure, and humidity are being controlled is called:

      (1) the operating area.
      (2) the conditioned area.
      (3) the system.

   b. Instruments such as thermostats that respond to changes in conditions are called:

      (1) operating relays.
      (2) high- and low-limit relays.
      (3) controlling instruments.

   c. Devices such as valves that directly affect actual conditions are called:

      (1) operating devices.
      (2) pressure controls.
      (3) system monitoring devices.

Written Test

d. Types of control systems include:

   (1) electric and electronic.

   (2) fluidic and pneumatic.

   (3) any of the above and combinations of any of the above.

5. Complete statements about switch configurations and symbols. Write in the word(s) or information that best completes each of the following statements.

   a. Switches may connect a circuit by using contact ________________, knifeblade contacts, mercury in a tube, solid state devices, and other means.

   b. Normally closed (NC) switches have the contacts ____________________ when there is no power in the circuit, or under normal operation.

   c. Normally open (NO) switches have the contacts ____________________ when there is no power in the circuit, or under normal operations.

   d. A NO switch "makes" when the contacts are ______________________ ____________________.

   e. A NC switch "breaks" when the contacts are ______________________.

   f. A switch that breaks at only one end is referred to as a ____________________ break, a switch that breaks at both ends is referred to as a _________________________ break.

   g. The number of ______________ of electricity that a switch can handle is described as its "pole," single pole, double pole, triple pole, or more.

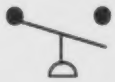
   h. The number of _____________________ a switch can be placed in, not counting "off" positions, is described as its "throw", single throw, double throw, or more.

   i. In symbols, dotted lines are used to connect switches tied together to act as _______________ controls.

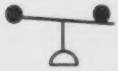
Written Test

6. Identify switch symbols. Place the number beside the switch description in the blank beside its illustration.

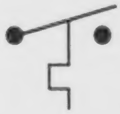
___ a.



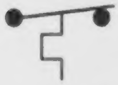
___ b.



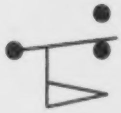
___ c.



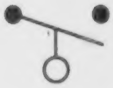
___ d.



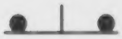
___ e.



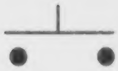
___ f.



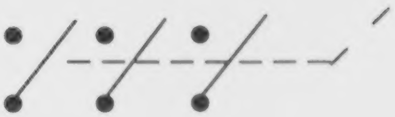
___ g.



___ h.



___ i.



1. SPST close on temperature fall
2. SPST close on liquid level rise
3. SPST double make NO push button
4. SPST close on pressure rise
5. SPDT change on increase in flow
6. SPST double break NC push button
7. TPST disconnect
8. SPST open on temperature rise
9. SPST open on pressure fall

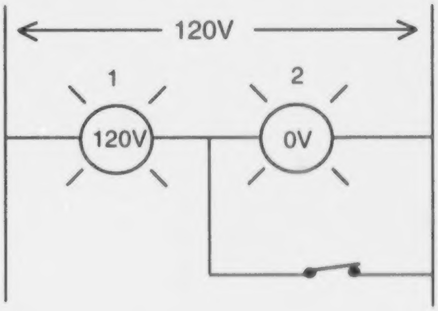
Written Test

7. Complete statements about applications of shunt circuits. Write in the word(s) or information that best completes each of the following statements.

   a. Shunt circuits "shunt" current around a load by taking advantage of the fact that electrical current takes the path of __________________ resistance.

   b. When loads placed in series are connected to a power source, the voltage drop at each load is in proportion to its ______________________.

   c. A switch can be used to route or shunt electricity around one of the loads causing the load to turn off, even though the load is not _________________________ from the source.



   d. In the example in item c, note that light 2 is off when the switch is "on" and that light 2 is on when the switch is "off"; remember that even when light 2 is not on it is still ___________________ to the power source.

   e. In a technical sense, the switch in the example in c should be referred to as "____________" or "_______________" rather than "on" or "off."

   f. Note that light 2 in the above examples goes on and off, but light 1 receives ____________________ amounts of voltage but never goes off.

   g. Variations of the shunt circuit are used in control circuits such as lock-in or lock-out circuits, defrost circuits, and __________ ________________ harvest circuits.

   h. _____________________ position switches often direct the current to one or more of several alternative paths rather than simply turning loads on or off.

Written Test

8. Select true statements about electronic switching. Place an "X" beside each true statement.

__ a. Electronic circuits use semiconductor devices to perform control and switch functions.

__ b. Current flow in a transistor is controlled by the voltage applied at the junction of the dissimilar materials.

__ c. Current flow through a diode is in two directions, and if you apply AC voltage to a diode, it will conduct only on each positive AC half-cycle.

__ d. Current flow through a zener diode is also in two directions depending on the amount of voltage applied.

__ e. Current flow through an SCR, silicon-controlled rectifier, is in one direction only and takes place only when a specified voltage threshold is reached at the gate.

__ f. Current flow through a TRIAC, which is two SCRs combined, is in both directions and takes place only when a specified voltage threshold is reached at the gate.

__ g. To form numbers and/or letters, indicators on control panels use special light emitting diodes, LEDs, which give off light when current passes through them.

9. Select true statements about protection devices. Place an "X" beside each true statement.

__ a. Protection devices are specialized switches used to protect equipment or circuits from excessive conditions.

__ b. Protection devices respond to conditions such as excessive current, low or high pressures, or high or low temperature.

__ c. Protection devices always respond to only one condition.

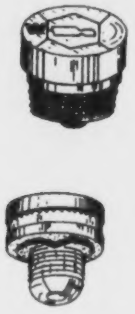
__ d. Protection devices are almost always manual reset.

Written Test

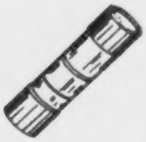
10. Identify overcurrent protection devices. Place the number beside the description of the device in the blank beside its illustration.

1. Breaker w/bimetallic strip
2. Ferrule-type cartridge fuse
3. Fusible link
4. Edison base plug fuse
5. Blade-type cartridge fuse
6. Type S fuse
7. R-rejection cartridge fuse

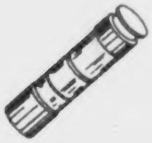
___ a.



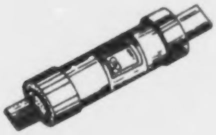
___ b.



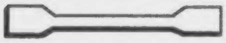
___ c.



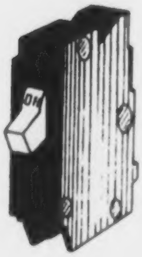
___ d.



___ e.



___ f.



___ g.

Written Test

11. Complete statements about pressure-actuated protection devices. Circle the number in front of the information that best completes each of the following statements.

    a. Refrigerant pressure controls interrupt the compressor motor circuit or the compressor motor control circuit if refrigerant:

        (1) pressure drops below control settings.

        (2) pressure exceeds control settings.

        (3) pressure drops below or exceeds control settings.

    b. Refrigerant pressure controls may have a manual or automatic reset, and may be:

        (1) high pressure.

        (2) low pressure.

        (3) both high and low pressure controls in a dual switch.

        (4) all of the above.

    c. An oil pressure control connects to both the oil pump and the compressor motor crankcase to monitor the difference between:

        (1) the oil pressure and the crankcase temperature.

        (2) the oil pressure and the crankcase pressure.

        (3) the oil pressure/temperature and the crankcase temperature/pressure.

    d. An oil pressure control interrupts the compressor motor circuit or the compressor motor circuit when:

        (1) the compressor runs low on oil.

        (2) the pressure differential drops below the factory setting.

        (3) the pressure differential rises above the factory setting.

12. Select true statements about motor protection devices. Place an "X" beside each true statement.

    __ a. Electrical devices which provide motor protection may be sensitive to current, temperature, or both.

    __ b. Motor protection devices are always internal, built into the motor windings.

    __ c. Electrical devices used for motor protection include bimetal overloads, magnetic overloads, thermal overload relays, lockout relays, and solid-state motor protectors.

Written Test

13. Complete statements about bimetal protection devices. Write in the word(s) or enter the information that best completes each of the following statements.

a. Bimetal protection devices operate on the principle that an increase in temperature causes a bimetal strip or disc to ____________.

b. The increase in temperature can be caused by excessive ________________ passing through the bimetal, or the bimetal's proximity to high temperatures.

c. When the bimetal warps, it opens or closes a set or sets of __________________.

d. Bimetal overloads may be line duty, in the line voltage circuit, or _______________ duty, in the control circuit.

e. A bimetal protection device may be a manual reset overload or an _____________________ reset overload.

f. Two common uses of bimetal protection devices are as _______________________limit switches and compressor overloads.

g. The symbol for a bimetal overload is:_______________________ or __________________.

h. The symbol for a thermal overload is:___________________________.

Written Test

14. Complete statements about protecting electronic devices. Circle the number in front of the information that best completes each of the following statements.

   a. Electronic circuits, and especially integrated circuits, are extremely sensitive to instantaneous voltage surges called:

      (1) transients.

      (2) variants.

   b. Variable resistors are used to protect electronic circuits from transients, and these resistors are called:

      (1) surge protectors.

      (2) varistors.

   c. During a voltage surge a varistor provides an alternate path that protects a transformer and other loads from damage, and this is because:

      (1) varistor resistance falls sharply during a voltage surge.

      (2) varistor resistance increases sharply during a voltage surge.

   d. To avoid creating static electricity transients when handling PC boards, avoid touching components any more than necessary, and:

      (1) avoid working with components on floors or areas where static electricity is present.

      (2) ground yourself before touching a PC board, and keep yourself grounded, if possible, while handling electrostatic-sensitive components.

Permission to duplicate this test is granted.

Controls and Protection Devices
Unit 5

Unit Evaluation Form

Student Name______________________________ Date_______ Unit Rating______

Job Sheet 1–Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Shunt Circuits With One SPST Switch Rating______

Comments:

Job Sheet 2–Draw Pictorials, Fabricate Working Models, a Draw Ladder Schematics for Circuits With 3-Way Switches Rating_______

Comments:

Job Sheet 3–Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Circuits With 3-Way and 4-Way Switches Rating______

Comments:

Job Sheet 4–Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Circuits With a Safety Switch Rating______

Comments:

Job Sheet 5–Draw a Pictorial, Fabricate a Working Model, and Draw a Ladder Schematic of a Basic Refrigerator Circuit Rating______

Comments:

Other:

Written Tests:____________ Pretest__________ Posttest_______

Total________

Teacher Signature ____ Date________

Student Signature ____ Date________

Permission to duplicate this form is granted.

Transformers and Relays
Unit 6

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan enrichment of exceptional students as well as accommodation of special needs students.
4. Add overheads or other graphic materials as desired to enhance instruction.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss and demonstrate the procedures in the job sheets. Review criteria for evaluating these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of written test. Add or modify test items as needed.
13. Give written test.

Suggested Activities

14. Compile assignment and job sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets added to the unit.

15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: a SCANS Report for America 2000.* These SCANS skills and competencies have been adapted by MAVCC to help instructors and program planners effectively articulate curriculum.

1. Have several different transformers on hand as students begin discussing Objective 2. Dismantle the transformers as needed so students can examine the coils and establish a good mental picture of what makes a transformer function. **Basic skills, science and listening.**

2. Have a control transformer for use in demonstrating Objective 3. Pick a 24V transformer that is common in ACR applications. Explain why the VA rating is extremely important. **Basic skills, science and listening.**

3. Spend time enough on Objective 5 to make sure students have command of expressing relay symbols in pictorials and on ladder schematics. By mastering the elements of Objective 5, students will find the job sheets much easier to complete. **Basic skills, science and listening.**

4. Stress the elements of safety when working with control relays and contactors as presented in Objective 6. Be sure students understand that because certain electrical tasks can be performed by other than a licensed electrician, it doesn't mean there is no electrical danger. A technician must be safety conscious at all times. **Basic skills, reading and listening.**

5. Assign students to small groups and have members of each group bring pictorials and ladder schematics or installation drawings from ACR equipment they find in their homes. Have the group present their findings to the class and concentrate on explaining why the manufacturer of the equipment included the type of diagrams they found. **Interpersonal skills, team work; basic skills, science and speaking.**

Suggested Activities

Resources Used in Developing This Unit

1. Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.

2. *The Air Conditioning, Heating and Refrigeration News HVAC/R Source Guide.* Troy, MI: Business News Publishing Company, 1995.

3. Wantiez, Gary W. *ACR Electrical Components and Systems.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.

4. Smreker, Eugene and King Calvert. *Major Appliance Repair.* Stillwater, OK: The Mid- America Vocational Curriculum Consortium, 1987.

Suggested Supplemental Resources

Transformer principles and relay principles are two major topics in the Honeywell text, *Fundamentals of Residential Controls.* The inexpensive text ($9.00) is one of Honeywell's programmed instruction books built around a step-by-step, question-answer format. Other topics include: nature of electricity; rules governing electricity; inductive and capacitive circuits; fundamentals of residential controls; power, basic motor operation; and analyzing control circuits. The Honeywell product number for this impressive 250-page workbook is 71-97083. Check with your local Honeywell distributor or call Honeywell at 1-800-345-6770. ext. 2040. You may also access the Honeywell website at **http://www.honeywell.com/controls.html.**

In their general training series, Carrier Training Services has several modules dedicated to the electrical elements of ACR training. Their are nine modules in their basic series, including *Module 8, Electronic Devices and Circuits.* Other modules range from introduction to electricity to electrical troubleshooting. The well executed series is enhanced with full color graphics and includes VHS videos, audio cassettes, and student workbooks. Quantity discounts are available for vo-tech schools and other training institutions. For a catalog of these and other materials from Carrier Training Services, write to:

Literature Services, Bldg. TR-8
P.O. Box 4808
Syracuse, NY 13221

Suggested Activities

Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Option A

4—Can perform job with no additional training.
3—Moderately skilled—Has performed job during training program; limited additional training may be required.
2—Limited skill—Has performed job during training program; additional training is required to develop skill.
1—Unskilled—Is familiar with process but is unable to perform job.

Option B

Yes—Can perform job with no additional training.
No—Is unable to perform job.

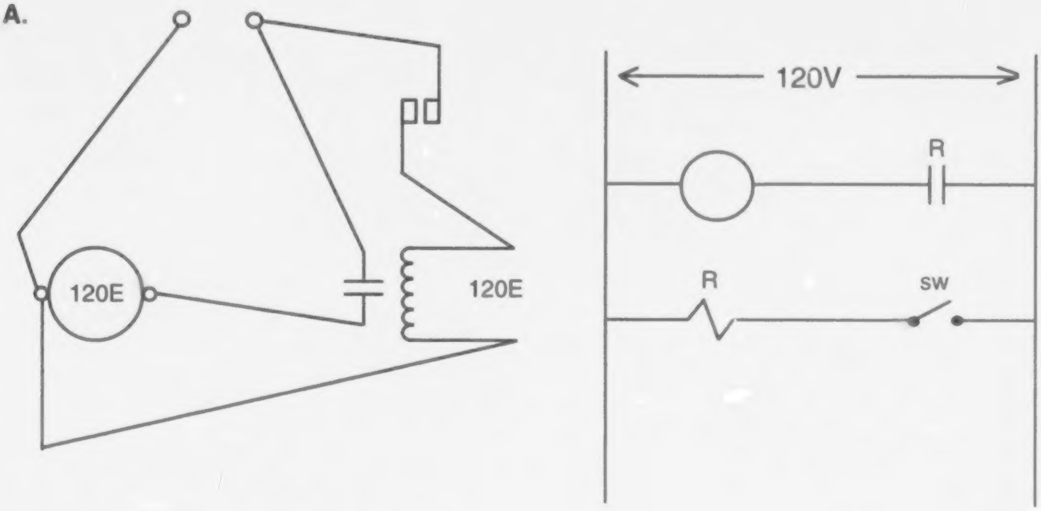
Transformers and Relays
Unit 6

Answers to Job Sheet Problems

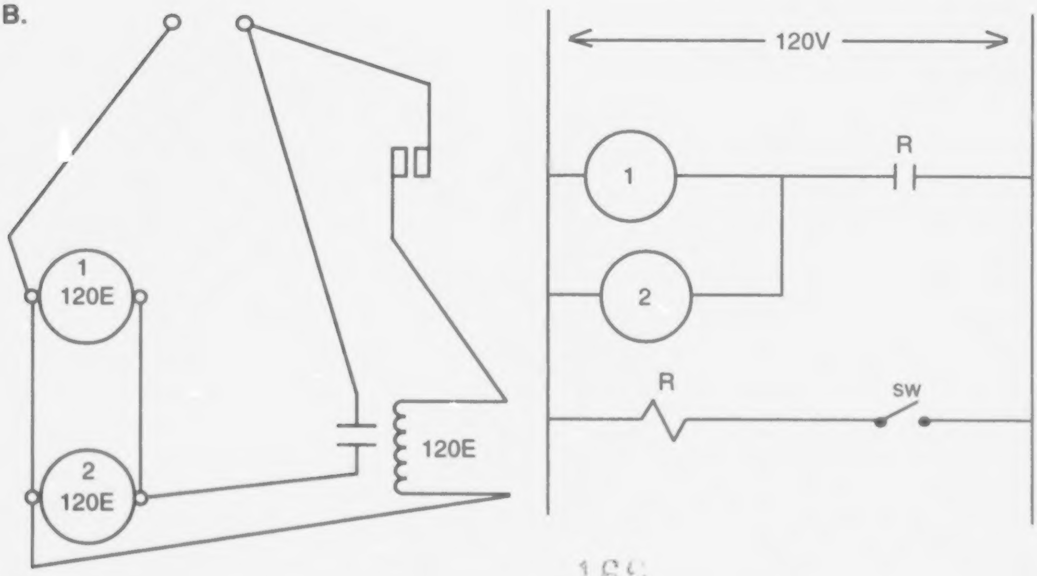
Job Sheet 6

Note: Drawings may vary, but circuits must meet specifications and schematics must match the pictorials.

A.


120E
120E
120V
R
R
SW

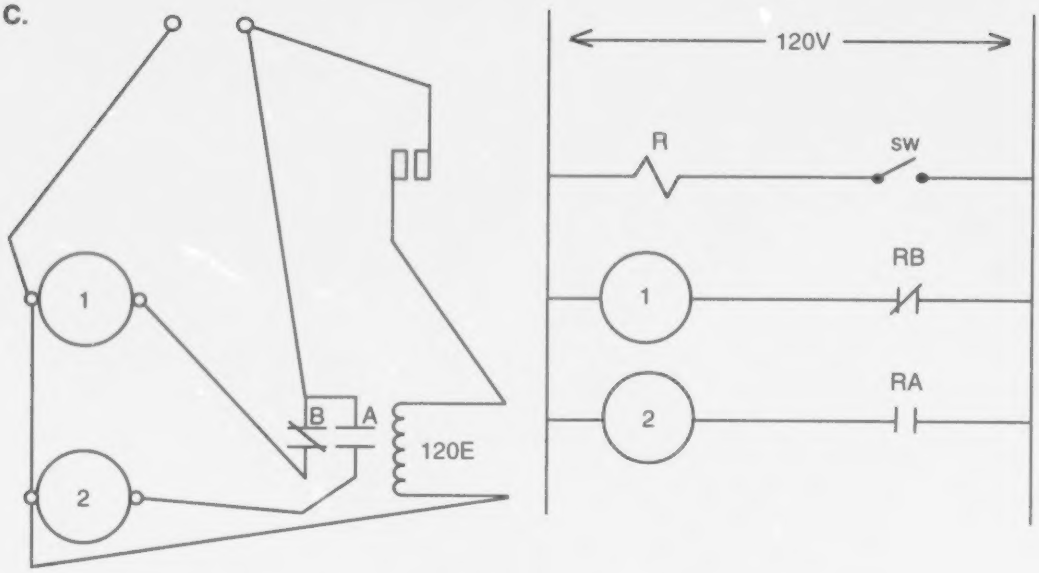
B.


1
120E
2
120E
120E
120V
1
2
R
R
SW

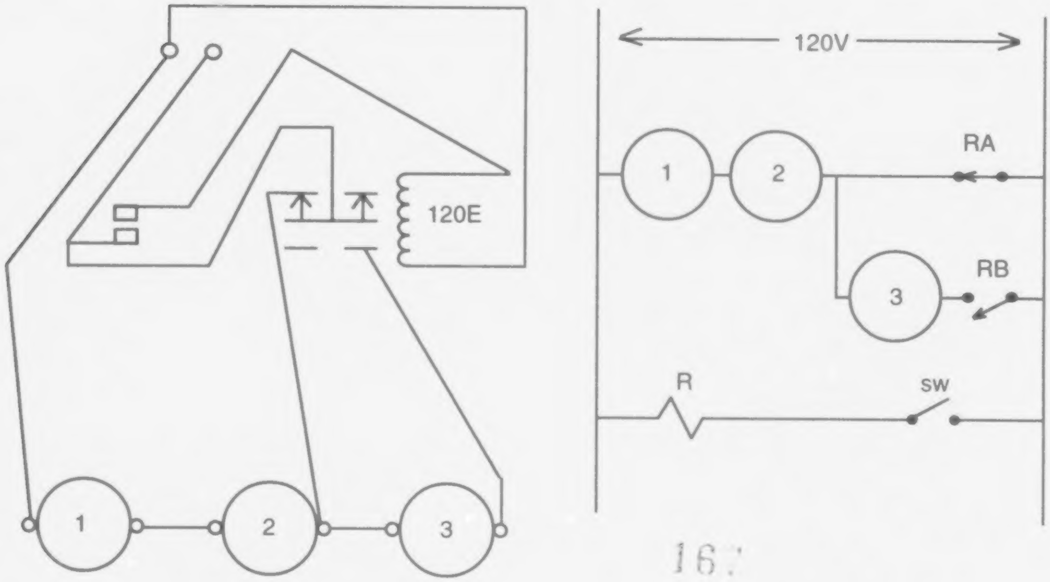
Answers to Job Sheet Problems

Job Sheet 6

C.


1
2
B
A
120E
120V
R
SW
1
RB
2
RA

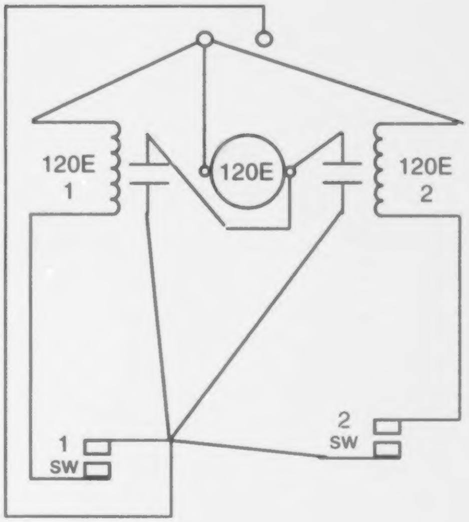
D.

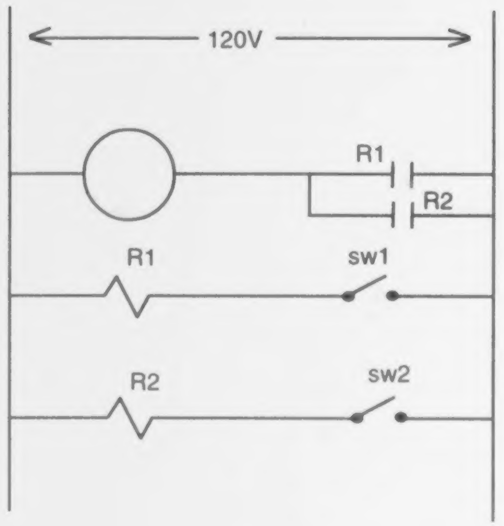

120E
1
2
3
120V
1
2
RA
3
RB
R
SW

Answers to Job Sheet Problems

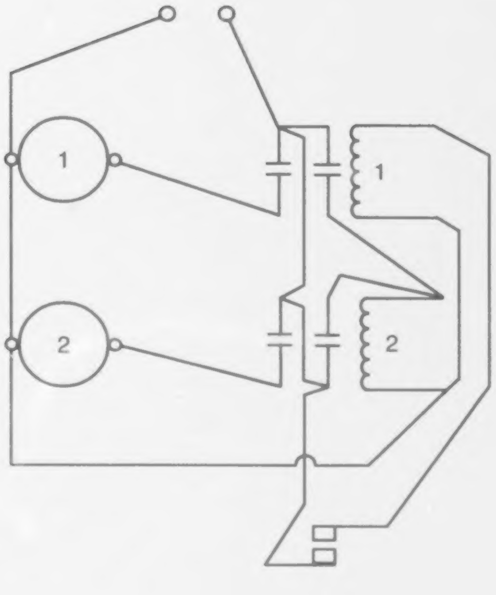
Job Sheet 7

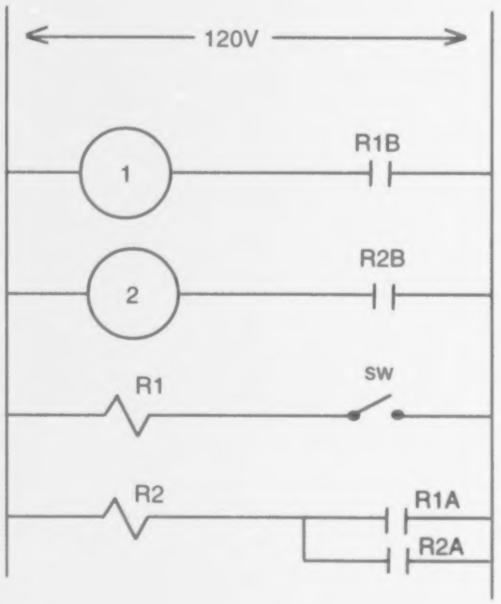
A.


120E
1
120E
120E
2
1
SW
2
SW


120V
R1
R2
R1
sw1
R2
sw2

B.

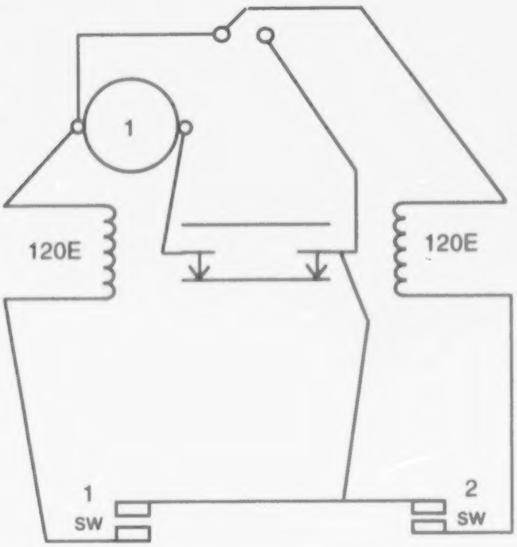


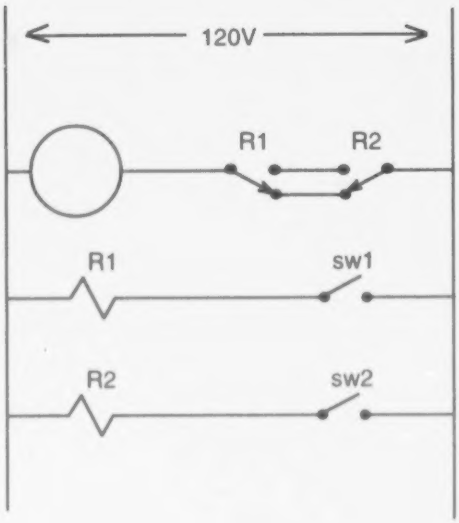

120V
1
R1B
2
R2B
R1
sw
R2
R1A
R2A

Answers to Job Sheet Problems

Job Sheet 7

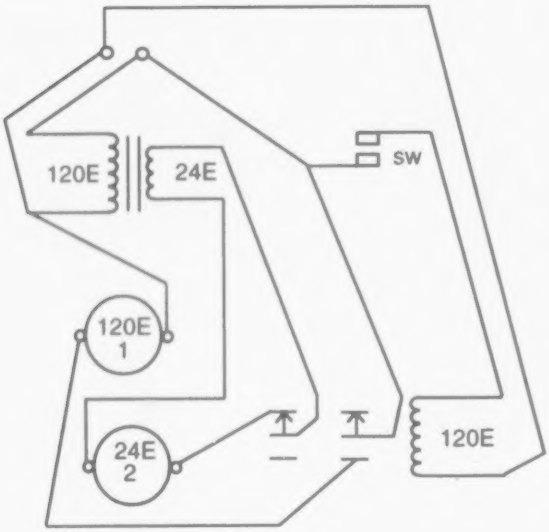
C.

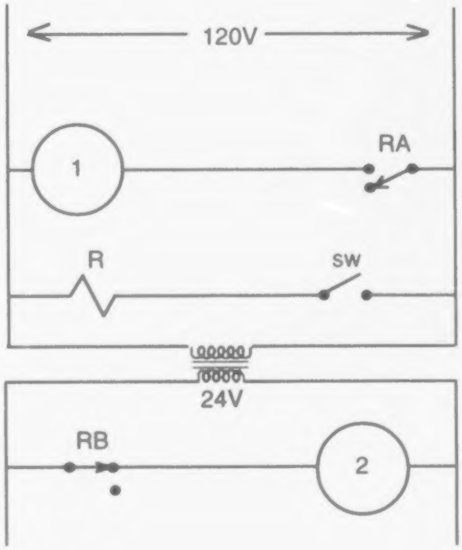

1
120E
120E
1
sw
2
sw


120V
R1
R2
R1
sw1
R2
sw2

Job Sheet 8

A.

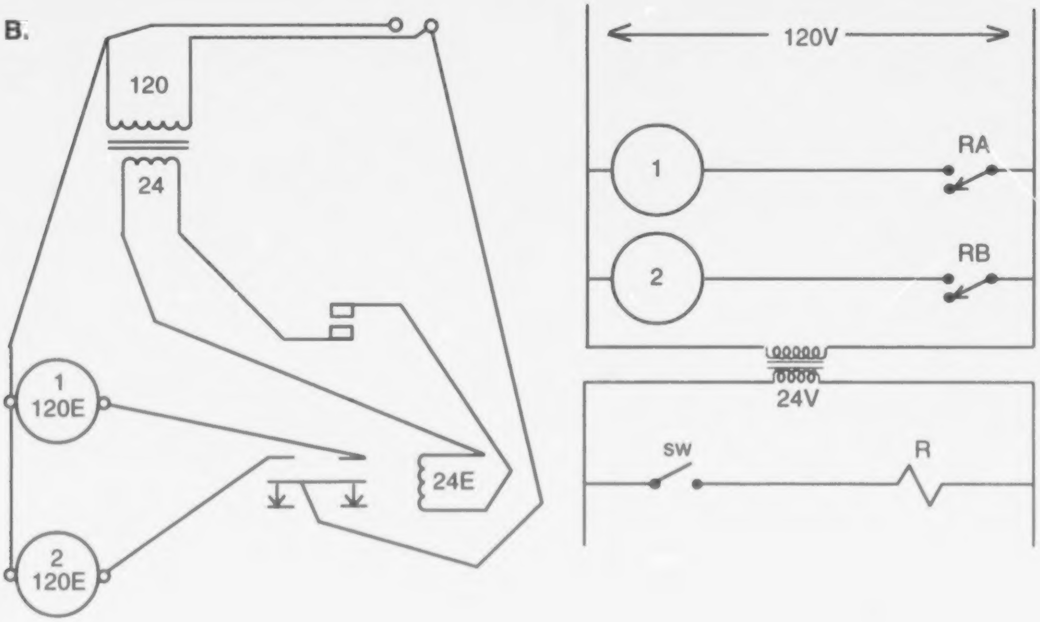

sw
120E
24E
120E
1
24E
2
120E


120V
1
RA
R
sw
24V
RB
2

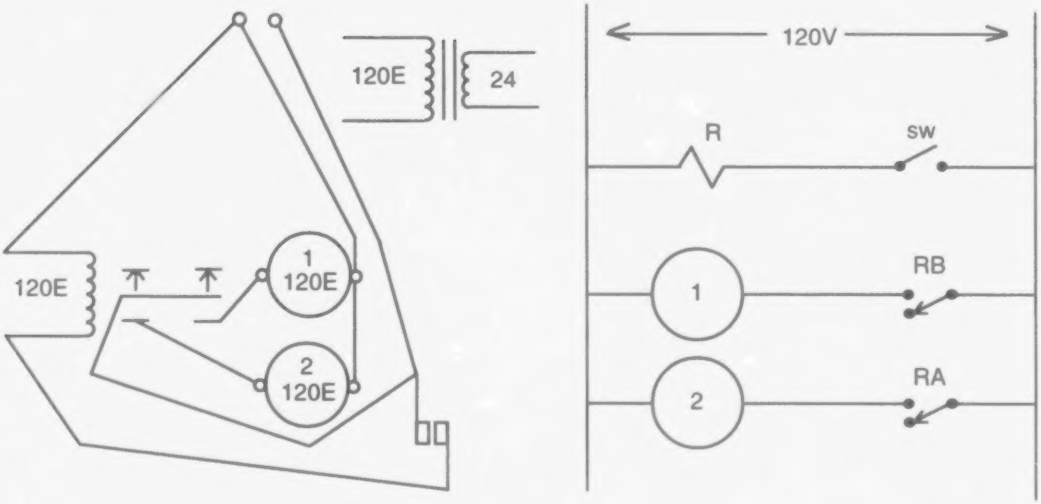
Answers to Job Sheet Problems

Job Sheet 8

B.


120
24
1
120E
2
120E
24E
120V
1
RA
2
RB
24V
SW
R

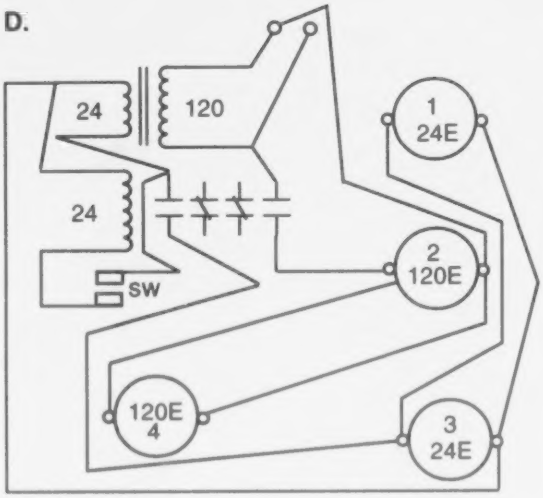
C.

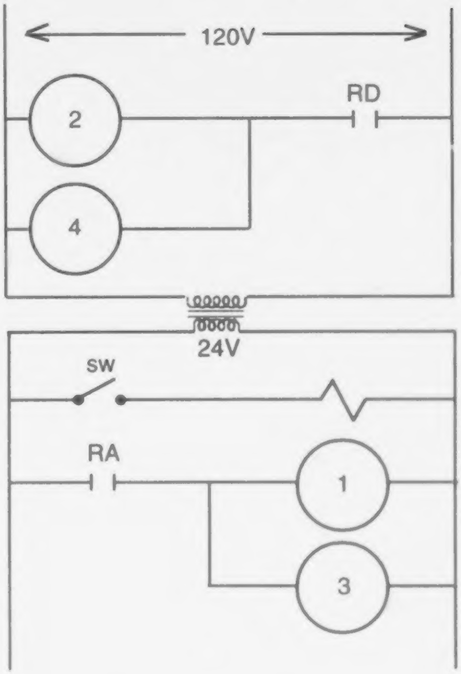

120E
24
120E
1
120E
2
120E
120V
R
SW
1
RB
2
RA

Answers to Job Sheet Problems

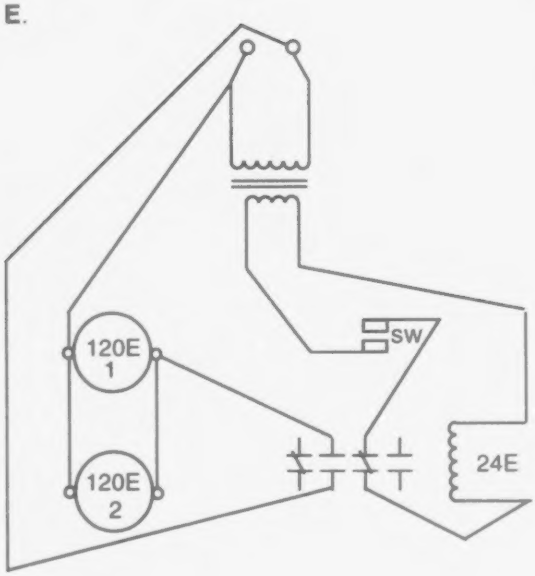
Job Sheet 8

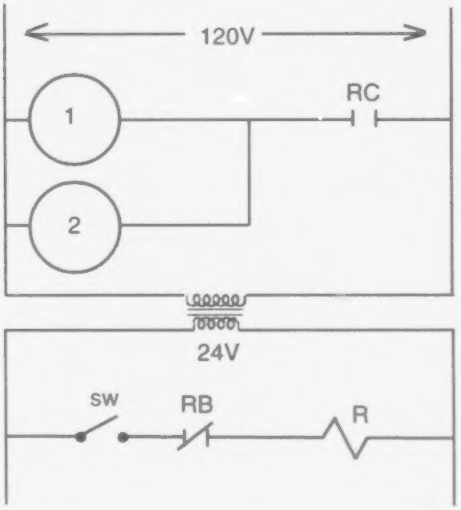
D.


24
120
24
SW
1
24E
2
120E
120E
4
3
24E


120V
2
RD
4
24V
SW
RA
1
3

E.

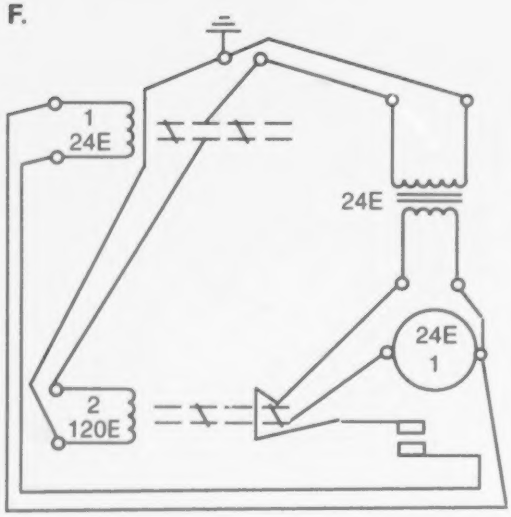

SW
120E
1
120E
2
24E

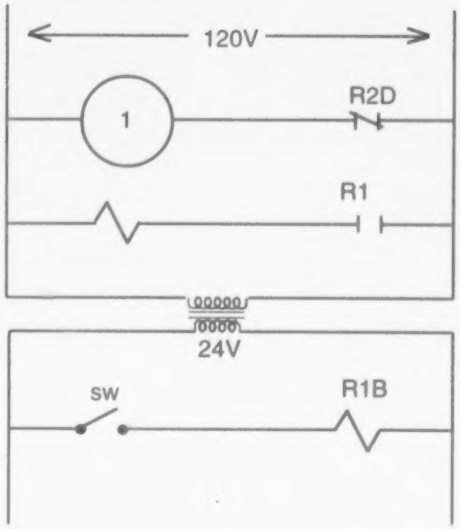

120V
1
RC
2
24V
SW
RB
R

Answers to Job Sheet Problems

Job Sheet 8

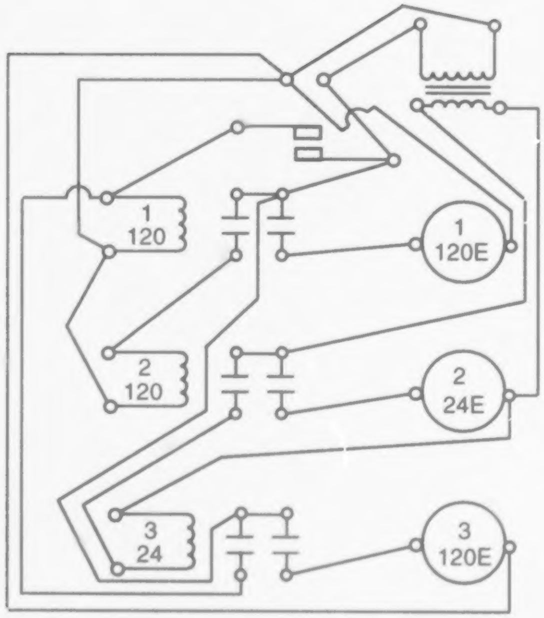
F.

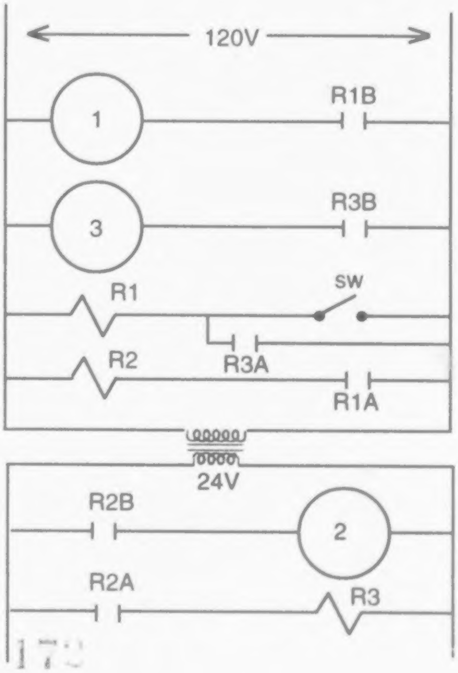

1
24E
24E
24E
1
2
120E


120V
1
R2D
R1
24V
SW
R1B

Job Sheet 9

A.

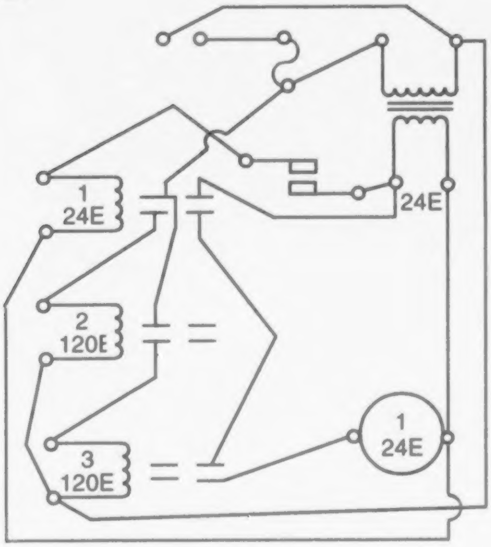

1
120
1
120E
2
120
2
24E
3
24
3
120E

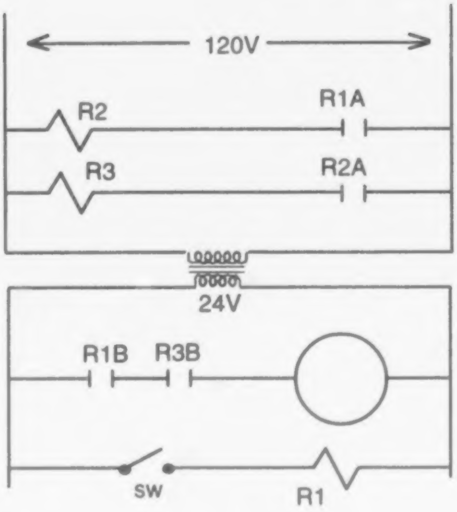

120V
1
R1B
3
R3B
R1
SW
R3A
R2
R1A
24V
R2B
2
R2A
R3

Answers to Job Sheet Problems

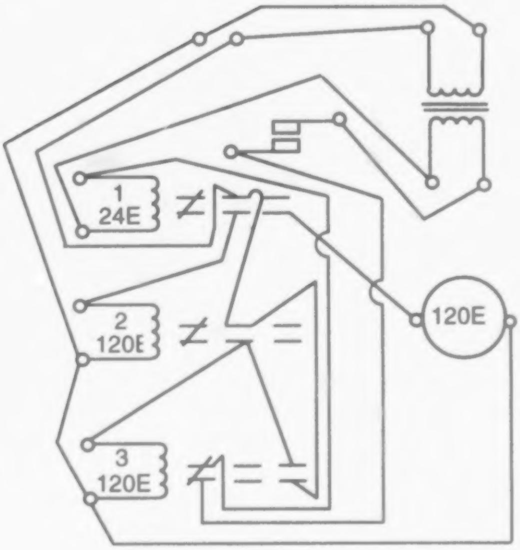
Job Sheet 9

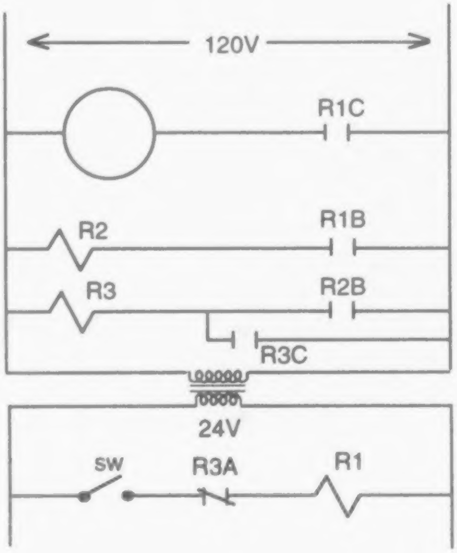
B.


1
24E
2
120E
3
120E
24E
1
24E


120V
R2
R1A
R3
R2A
24V
R1B
R3B
SW
R1

C.


1
24E
2
120E
3
120E
120E


120V
R1C
R2
R1B
R3
R2B
R3C
24V
SW
R3A
R1

Transformers and Relays
Unit 6

Answers to Written Test

1. a. 7
   b. 4
   c. 6
   d. 3
   e. 2
   f. 1
   g. 5

2. a. primary, secondary (order may be reversed)
   b. magnetic
   c. induce
   d. ratio

3. a. stamped, printed
   b. stamped, printed, secondary, secondary
   c. secondary
   d. greater
   e. internal fuse

4. a. (2)
   b. (1)
   c. (1)
   d. (1)
   e. (2)

5. a, b, c, d (all statements are true)

6. a, b, d, e

7. a. (3)
   b. (1)

8. a. 2
   b. 6
   c. 3
   d. 5
   e. 1
   f. 4

9. a, d, e

Answers to Written Test

10. a. (2)
    b. (1)
    c. (2)
    d. (2)

11. a. line voltage
    b. run
    c. start
    d. L, M, S (order may vary)
    e. (1) serial
       (2) model
       (3) horsepower (or amperage)
       (4) amperage (or horsepower)
       (5) relay

12. a. EMF
    b. line, drop out
    c. Line
    d. Constant-coil
    e. Pick-up
    f. drop out
    g. 75%
    h. 25%
    i. minimal
    j. run capacitor

13. a. (2)
    b. (1)
    c. (1)

14. a. (3)
    b. (1)
    c. (2)
    d. (3)

15. a, c, d, e

Transformers and Relays
Unit 6

Written Test

Name ______________________________ Date __________ Score ________

1. Match each term below with its correct definition.

___ a. A control relay rated at approximately 25A or higher which is usually energized by a control circuit, and which usually opens and closes a line voltage circuit

___ b. A relay that controls a line voltage load by means of control voltage

___ c. A transformer used in a class 2 circuit

___ d. 5V to 30V used in control circuits which are referred to by the NEC as class 2 circuits

___ e. Voltage supplied for use by residential and commercial consumers, usually 110V to 600V

___ f. An electromagnetic switch

___ g. A national organization dedicated to writing standards for the safe use and application of electrical materials and devices

1. Relay
2. Line voltage
3. Control voltage
4. Control relay
5. UL
6. Control transformer
7. Contactor

2. Complete statements about how a transformer works. Write in the word(s) or information that best completes each of the following statements.

a. A transformer is made by wrapping two wires close to each other around an iron core so that they form ____________ and ________________ coils.

b. When voltage flows through the primary coil, a ____________________ field builds up around the primary coil.

c. The arrangement of the coils causes most of the lines of force to cut across the secondary coil, and _________________ voltage in the secondary coil.

d. The amount of voltage induced in the secondary coil depends upon the____________ of the number of wraps in the primary coil to to the number of wraps in the secondary coil.

3. Complete statements about control transformer specifications. Write in the word(s) or information that best completes each of the following statements.

   a. The Primary Voltage and the Secondary Voltage ratings are _____________or _____________ on control transformers.

   b. Another important transformer rating, ____________ or ______________ on the transformer, is the VA rating which is the rated ________________ voltage (V) times the maximum safe _______________________ load in amperes (A).

   c. The VA rating determines the maximum current draw of the loads that can safely be connected to the ____________________ side of the transformer.

   d. Take care to select replacement transformers with the same voltage ratings as the original transformer, and with a VA rating equal to or ___________________ than the VA rating of the original transformer.

   e. NEC class 2 transformers with a secondary voltage over 15V must have an _____________________ ____________ of 3.2A or less to meet UL requirements.

4. Complete statements about providing DC power. Circle the number in front of the information that best completes each of the following statements.

   a. Since only AC voltage is available to power most ACR equipment, the low-level DC voltages necessary for electronic circuits are obtained by:

      (1) adding special packages that provide DC voltages.

      (2) converting the available AC voltage to DC voltage.

   b. Using diodes to convert AC voltage to DC voltage is called

      (1) rectification.

      (2) transistorization.

   c. A DC power supply is made up of:

(1) a center-tapped transformer, if needed, a rectifier, a filter, and a voltage regulator.

(2) a full-wave bridge and a voltage regulator.

d. A full-wave rectifier requires a center-tapped transformer and another type of full-wave rectifier called a bridge rectifier does not require a special transformer, but with all full-wave rectifiers:

(1) a filter must be used to smooth out the ouput and eliminate noise that can affect the operation of nearby appliances such as TVs.

(2) a special limiting diode must be used to stabilized the rectified current.

e. Fluctuations in the voltage when there are variations in the source voltage or the load circuit are controlled by:

(1) a stabilizing bridge.

(2) a voltage regulator.

5. Select true statements about relay components and uses. Place an "X" beside each true statement.

__ a. Most relays consist of a coil and one or more sets of contacts.

__ b. In most relays, when the coil is energized, it creates an electromagnet which attracts some type of iron lever which operates contacts.

__ c. Relays use one circuit, usually a control circuit, to connect and disconnect another circuit.

__ d. Relays are used for two major purposes, as control relays or motor starting relays.

6. Select true statements about using relay symbols in electrical drawings. Place an "X" beside each true statement.

__ a. Relay coils are loads and therefore are usually connected in a separate circuit on a pictorial diagram.

__ b. Each relay coil will usually appear on a separate rung of a ladder schematic diagram.

__ c. Relay contacts are placed in the circuit or on the rung with the load that they control which is usually the same rung as the relay coil.

__ d. When more than one relay is involved, each relay must be designated with a number, letter, or name.

__ e. If a relay has more than one set of contacts, each set of contacts must be designated with a number or letter.

__ f. Relay contacts on a drawing are usually lettered or numbered in order from the outside to the coil.

7. Solve problems about control relays and contactors. Circle the number in front of the information that best solves each of the following problems.

a. Two coworkers are discussing whether a 27A control relay is in fact a control relay or a contactor. The problem is that the discussion is turning into an argument, so to solve the problem, you could:

(1) Tell them that only relays rated 30A or above are called contactors.

(2) Tell them that relays rated below 30A are, in fact, called relays.

(3) Tell them that these devices in the 25A to 30A range may be called either a control relay or a contactor.

b. A coworker says that using low voltage control circuits to control high amperage line voltage loads from a remote location is really done to avoid having to comply with code requirements. The coworker has the right information but the wrong idea, so to solve the problem, you could:

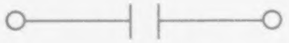
(1) Remind your coworker that the situation allows installers to use smaller wires which are not subject to many code requirements, so it is not an attempt to avoid codes at all, but to permit the installation of controls such as thermostats by a qualified technician who doesn't have to be a licensed electrician.

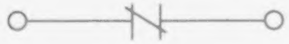
(2) Remind the coworker that most ACR technicians know as much about electricity as electricians do.

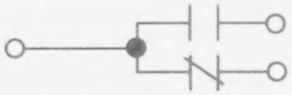
(3) Remind your coworker that codes vary from area to area and that what is being said may apply in one place but not in another.

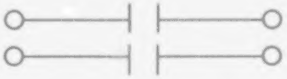
Written Test

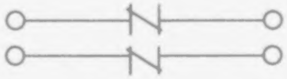
8. Match control relays and contacts with their switching arrangements. Place the number of the abbreviation for the switching arrangement in the blank beside its illustration.

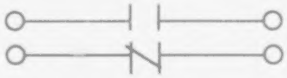
___ a. 

___ b. 

___ c. 

___ d. 

___ e. 

___ f. 

1. DPST NC
2. SPST NO
3. SPDT
4. DPST NC and NO
5. DPST NO
6. SPST NC

9. Select true statements about types of motor starting relays and their uses. Place an "X" beside each true statement.

___ a. Many hermetic motors require the starting assistance of a start winding and/or start capacitor which must be disconnected after the motor starts, and the disconnect is accomplished by a relay called a motor starting relay.

___ b. Some hermetic compressor motors require external starting devices, but most do not.

___ c. Motor starting relays respond only to voltage.

___ d. Current relays include both the coil-type and hot wire-types and are used on many domestic refrigerator and freezer compressors.

___ e. Voltage relays are referred to as potential relays and are used on air conditioning and commercial refrigeration compressors.

___ f. Solid-state replacements are available for only a limited number of relay replacements.

10. Complete statements about motor starting relay operations. Circle the number in front of the information that best completes each of the following statements.

a. Current relays respond to the amperage draw of:

(1) the start windings of a compressor motor.

(2) the run windings of a compressor motor.

Written Test

b. Coil-type current relays have normally open contacts in the starting winding circuit which close in response to the high starting amperage and open:

(1) when amperage drops to the lower running amperage.

(2) when at least a 2-second interval has passed.

c. When speaking about a positional coil-type current relay, it means:

(1) the relay must be placed at a certain point near a compressor motor.
(2) the relay has to be installed as installation arrows or labels indicate.

d. Hot-wire type relays also function as overloads since they have normally closed contacts in the run winding circuit which open if:

(1) low amperage continues for longer than a few seconds.

(2) excessive amperage cpntinues longer than a few seconds.

11. Complete statements about motor starting current relay specifications. Write in the word(s) or information that best complete each of the following statements.

a. Terminal L connects to ______________ ______________.

b. Terminal M connects to the motor ______________ winding.

c. Terminal S connects to the motor ______________ winding.

d. Terminal designations 1, 2, and 3 may be used instead of _____ , _____ , and _____ .

e. Replacement relay specifications include voltage, position, if positional, and:

(1) equipment model and ______________ number.

(2) compressor motor ______________ number.

(3) compressor motor ______________ .

(4) compressor motor ______________ .

(5) original ______________ part number.

Written Test

12. Complete statements about motor starting voltage relay (potential relay) operations. Write in the word(s) or information that best completes each of the following statements.

    a. A potential relay is a motor starting relay that operates off the back _____ generated in the start winding.

    b. Potential relays have several voltage ratings, _______________ voltage, constant-coil voltage, pick-up voltage, and ________________ voltage.

    c. ___________ voltage is the source voltage being applied to the motor.

    d. ___________ - ___________ or continuous voltage is the back EMF generated in the compressor motor start windings.

    e. ___________ - ________ voltage is the minimum and maximum voltages at which the relay will energize.

    f. The _______ - ________ voltage is the minimum and maximum voltages at which the relay will deenergize.

    g. Back EMF increases across the start windings as the motor picks up speed; at approximately ___________ of operating speed, pick-up voltage is reached, the potential relay is energized, and the relay contacts disconnect the start components.

    h. Back EMF decreases as the motor slows down; at approximately _____________________ of operating speed, voltage decreases to drop out voltage, the potential relay is deenergized, and the relay contacts reconnect the start components.

    i. A solid state hard start assist device can be used in place of a potential relay and start capacitor when _______________ start assist is required.

    j. The solid state device is a PTC resistor which is usually simple to install at the __________ __________________ terminals.

13. Select true statements about potential relay specifications. Circle the number in front of the item that makes each of the following statements true.

    a. Terminal 1 on a potential relay connects to the start capacitor, but terminal 2 on the relay should connect to:

        (1) the motor common terminal

        (2) the motor start winding or the wire going to the start winding.

Written Test

b. Terminals 3, 4, and 6 on a potential relay are simply points for wire connections, but terminal 5 connects to:

   (1) the common terminal on the motor or the wire going to the common terminal.

   (2) the run winding.

c. Replacement specifications for potential relays include the equipment model and serial numbers along with the compressor model number, but other items that might be included are:

   (1) the original relay part number and compressor motor horsepower.

   (2) type of system with which the component is being used.

14. Complete statements about time delay relays. Circle the number of the item that best completes each of the following statements.

a. Time delay relays delay or sequence the energizing of loads such as:

   (1) delaying the restart of an air conditioning compressor.

   (2) sequencing electric furnace elements.

   (3) all of the above.

b. Time delay relays may operate line or low voltage devices to accomplish their purposes, and they are energized:

   (1) with low or line voltage.

   (2) with a transformer designed especially for time delay relays.

   (3) with regular 24V transformers.

c. Time delay relays may be actuated by solid-state components or a motorized cam, and also by:

   (1) an in-line contractor.

   (2) a thermostatic control.

   (3) a thermal warp switch which is usually a bimetal device.

Written Test

d. Solid-state time delay relays are popular for preventing:

  (1) overheating.

  (2) pressure buildup.

  (3) short cycling.

15. Select true statements about electronic controls for timed functions. Place an "X" beside each true statement.

Note: For a statement to be true, all parts of the statement must be true.

__ a. Many electromechanical components used for timed functions are being replaced by electronic versions.

__ b. Electronic versions are complex and difficult for a technician to troubleshoot.

__ c. The electronic version is packaged on a single PC board or sealed electronic module which must be replaced if it is receiving the correct input signals, but is not delivering the correct output signals to loads it controls.

__ d. Electronic time delays will usually have a feature that allows a service technician to bypass the time delay by placing a jumper across designated terminals on the board.

__ e. Examples of electronic controls used for timed functions include:

  (1) setback thermostats.

  (2) compressor start delays.

  (3) fan start delays.

  (4) fan shut-off delays.

  (5) defrost controls.

Permission to duplicate this test is granted.

Transformers and Relays
Unit 6

Unit Evaluation Form

Name______________________ Date________ Overall Rating________

Assignment Sheet 1—Identify Selected Relays Comments:	Rating_____
Job Sheet 1—Check Current Relays With an Ohmmeter Comments:	Rating_____
Job Sheet 2—Check Potential Relays With an Ohmmeter Comments:	Rating_____
Job Sheet 3—Check Current Relays With an Ammeter and a Voltmeter Comments:	Rating_____
Job Sheet 4—Check a Potential Relay With an Ammeter and a Voltmeter Comments:	Rating_____
Job Sheet 5—Install a Solid-State, Time-Delay Relay Comments:	Rating_____
Job Sheet 6—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Circuits With Basic Relays Comments:	Rating_____
Job Sheet 7—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Circuits With Dual Relays Comments:	Rating_____
Job Sheet 8—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Circuits With Special Applications Comments:	Rating_____
Job Sheet 9—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Circuits With Multiple Relays Comments:	Rating_____

Unit Evaluation Form

Other:		
Written Test:____________	Pretest:__________	Posttest:______ total ______
Teacher Signature: ________________________________		Date:__________
Student Signature: ________________________________		Date:__________

Permission to duplicate this form is granted.

Thermostats
Unit 7

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan enrichment of exceptional students as well as accommodation of special needs students.

4. Add overheads or other graphic materials as desired to enhance instruction.

5. Develop teaching plan. Adjust for different learning styles.

6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.

8. Discuss unit and specific objectives.

9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.

10. Discuss and demonstrate the procedures in the job sheets. Review criteria for evaluating these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

12. Make copies of written test. Add or modify test items as needed.

13. Give written test.

Suggested Activities

14. Compile job sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets added to the unit.

15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: A SCANS Report for America 2000*. These SCANS skills and competencies have been adapted by MAVCC to help instructors and program planners effectively articulate curriculum.

1. Have sample thermostats available to use for demonstrating various parts of thermostats as they are presented in this unit. Arrange students in groups and have each group identify one of the thermostat types presented in Objective 2. Have the groups report to the class about the characteristics of the thermostat they evaluated. **Interpersonal skills; teamwork, working with others to achieve a common goal; basic skills, speaking.**

2. Have a variety of temperature sensors available to demonstrate materials in Objective 3. **Basic skills, science and listening.**

3. Have samples of mechanical contacts and mercury-bulb contacts available to demonstrate materials in Objective 4. Be sure to demonstrate how the mercury-bulb switches can be configured for single pole, single throw, or single-pole, double throw action. **Basic skills, science and listening.**

4. When discussing Objectives 5, 6, and 7, stress the importance of the various parts of thermostats. Make sure students fully understand heat and cooling anticipation and how to work with heat and cooling anticipators on thermostats. **Basic skills, reading and listening.**

5. Have good samples of multistage thermostats available to demonstrate materials in Objective 9. **Basic skills, science and listening.**

6. When students discuss Objective 10, have samples of color coding available, and impress upon students the importance of matching subbases with the stages of heating and cooling that have to be controlled. **Basic skills, science and listening.**

Suggested Activities

7. Assign students to teams and have each team find and evaluate a programmable controller at a school facility. Have each team report on the brand name of the thermostat, temperature settings, and time periods for either winter setback or the setup times and temperatures for summer operation. **Interpersonal skills: teamwork, working cooperatively with others to achieve a common goal. Basic skills: speaking.**

8. Stress safety throughout the unit, especially for installation procedures covered in Objective 8. **Basic skills, listening.**

9. Because of the variety of equipment available locally, job sheets for replacing line-voltage thermostats on window air conditioning and refrigerators were purposely omitted from this unit. The activity will be more meaningful if you prepare job sheets for equipment available locally and then evaluate student skills in the "Other" category on the Unit Evaluation Form. **Basic skills, science.**

Resources Used in Developing This Unit

1. Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.

2. *The Air Conditioning, Heating and Refrigeration News HVAC/R Source Guide.* Troy, MI: Business News Publishing Company, 1995.

3. Wantiez, Gary W. *ACR Electrical Components and Systems.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.

4. Smreker, Eugene and King Calvert. *Major Appliance Repair.* Stillwater, OK: The Mid- America Vocational Curriculum Consortium, 1987.

Suggested Supplemental Resources

Fundamentals of residential controls is a major topic in the Honeywell text by the same name, *Fundamentals of Residential Controls.* The inexpensive text ($9.00) is one of Honeywell's programmed instruction books built around a step-by-step, question-answer format. Other topics include: nature of electricity; rules governing electricity; inductive and capacitive circuits; motor operation principles; power, transformer principles; relay principles; and analyzing control circuits. The Honeywell product number for this impressive 250-page workbook is 71-97083. Check with your local Honeywell distributor or call Honeywell at 1-800-345-6770, ext. 2040. You may also access the Honeywell website at **http://www.honeywell.com/controls.html.**

Since the name Honeywell is synonymous with thermostats, they have available several service/training texts on a variety of Honeywell thermostats. These include *Operation of Microelectronic Thermostats, Principles of Microelectronic Control, Saving Energy With Temperature Offset, Heat Pump Thermostats,* and others. For these specific service texts, contact Honeywell at one of the sources given above.

Suggested Activities

Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Option A

4—Can perform job with no additional training.
3—Moderately skilled—Has performed job during training program; limited additional training may be required.
2—Limited skill—Has performed job during training program; additional training is required to develop skill.
1—Unskilled—Is familiar with process but is unable to perform job.

Option B

Yes—Can perform job with no additional training.
No—Is unable to perform job.

Thermostats
Unit 7

Answers to Written Test

1. a. 6 e. 5
   b. 4 f. 1
   c. 7 g. 8
   d. 3 h. 2

2. a. heating, cooling, refrigeration (order may vary)
   b. single, manual
   c. automatically
   d. electronic
   e. humidity
   f. (1) low
      (2) line
      (3) millivolt
   g. explain

3. a. (2)
   b. (1)
   c. (2)
   d. (2)
   e. (1)
   f. (2)

4. a. (2)
   b. (1)
   c. (2)

5. a. (1)
   b. (2)
   c. (3)
   d. (2)

6. a. overshoot
   b. overshoot, off
   c. warms, heating
   d. 1°
   e. adjustable, current draw

Answers to Written Test

7. a. warmer
   b. cooling, exceeds
   c. cooling, not being
   d. 1°

8. a. (1)
   b. (2)
   c. (2)
   d. (2)

9. a. temperature
   b. (1) single-stage
      (2) single-stage
      (3) single-stage
      (4) single-stage
      (5) two-stage
   c. mercury, bimetal
   d. 2°
   e. 2°, 4°
   f. 2°, 4°
   g. compressors
   h. heat pump

10. a. selected, installed
    b. stages
    c. several different
    d. fan, damper, reversing
    e. terminals
    f. (1) R
       (2) G
       (3) W
       (4) Y
       (5) B
       (6) O
    g. color code
    h. insulation
    i. H_1, W_1; H_2, W_2
    j. Rh, Rc
    k. Rh, Rc

Answers to Written Test

11.
   - a. 5
   - b. 8
   - c. 3
   - d. 10
   - e. 2
   - f. 4
   - g. 6
   - h. 1
   - i. 9
   - j. 7

12.
   - a. (2)
   - b. (2)

13. a, b, c, d, f, h

14. a, b, c, d, e, f, h

15.
   - a. (2)
   - b. (1)
   - c. (2)

Thermostats
Unit 7

Written Test

Name ______________________________ Date ________ Score ______

1. Match each term on the right with its correct definition.

__ a. Causing heating or cooling equipment to respond before conditioned space temperatures reach desired settings

__ b. The difference between the minimum and maximum temperature to which a thermostat responds when the thermostat is set to a desired setting

__ c. Having to do with electrical circuits or equipment using semiconductors

__ d. AC voltage of more than 30V, but usually refers to 110V AC or more

__ e. AC voltage of 30V or less as used in ACR control circuits

__ f. One thousandth of a volt

__ g. A device which senses or "feels" temperature and conveys that temperature reading to other devices

__ h. A device which senses temperature conditions and controls circuits which activate equipment to effect changes in those conditions

1. Millivolt
2. Thermostat
3. Line voltage
4. Differential
5. Low voltage
6. Anticipation
7. Electronic
8. Temperature sensor

2. Complete statements about thermostat types and their applications. Write in the word(s) or information that best completes each of the following statements.

a. Thermostats are controls used to cycle ____________________, ____________________, and ____________________ equipment.

b. Thermostats for equipment such as window air conditioners, refrigerators, floor furnaces, and unit heaters respond to only a ______________ condition and usually have a single ______________ setting.

c. Thermostats for central heating and cooling systems may be manually set or may be capable of __________________ switching to heating or cooling, or changing their own settings at predetermined times.

d. Thermostats may be completely mechanical, state-of-the-art __________________, or some combination of the two.

e. Thermostats may be part of a complete control center which responds to conditions other than temperature, conditions such as __________________ or air quality.

f. Thermostat applications vary with their operating voltages:

   (1) __________ voltage such as in central heating and cooling systems;

   (2) __________ voltage such as in window air conditioners and domestic and commercial refrigeration;

   (3) _____________ circuits such as in some wall heaters, floor furnaces, and central heating units.

g. ACR technicians must be able to install, operate, and service different types of thermostats and ______________________ thermostat operations to a customer.

3. Complete statements about temperature sensors. Circle the number in front of the information that best completes each of the following statements.

   a. A temperature sensor:

      (1) reacts to temperature change and is always a bimetal strip.

      (2) reacts to temperature change and is the main component of a thermostat.

   b. A bimetal strip operates on the principle that:

      (1) two metals fastened together will expand at different rates when heated.

      (2) two metals fastened together will create an electrical circuit when heated.

Written Test

c. A rod and tube type temperature sensor is just a variation of:

   (1) a bulb and tube sensor.

   (2) a bimetal sensor.

d. A gas/liquid-filled bulb sensor:

   (1) is also known as an expansion-type sensor.

   (2) is also know as a tube and bellows sensor.

e. Electrical resistance sensors:

   (1) change resistance as their temperatures change.

   (2) accelerate bimetal strip action.

f. Thermocouple type sensors use the principle that:

   (1) when metals are bonded together, they generate electricity.

   (2) certain metals bonded together create very small amounts of electricity when heated.

4. Solve problems about electrical contacts. Circle the number in front of the statement that best solves each of the following problems.

   a. A classmate talking about mechanical contacts says the contacts have a snap action because the bimetal sensing strip is highly sensitive to temperature changes. Your classmate is partially correct, but the problem is:

      (1) The bimetal sensing strip has extra-sensitive contacts that cause the snap action.

      (2) There is a permanent magnet built into the contact so that when the bimetal strip starts movement, the magnet causes it to snap shut on the opposite contact, and this prevents arcing.

      (3) One of the metals in the bimetal strip is actually a flat spring that snaps the opposite direction when heated.

Written Test

b. A technician working on a mercury-tube thermostat says that the mercury is hermetically sealed in a tube to make sure it does not leak. The technician is partially correct, but the problem is:

  (1) Keeping the mercury enclosed is only one reason the device is built the way it is. Hermtically sealing a tube around the mercury globule also keeps out dust and humidity.

  (2) Keeping the mercury enclosed is only one reason the device is made the way it is. Hermetically sealing a tube around the mercury prevents static electricity from affecting operation.

  (3) The technician should have also mentioned that there is no other way to protect the mercury.

c. A technician replacing a mercury-tube thermostat puts the thermostat into place so that it is not quite level. The problem is:

  (1) The thermostat will look better if it is level.

  (2) The mercury-tube thermostat has to be installed level or it will not function properly.

  (3) The mercury-tube thermostat will still operate properly, but by not being level it will not respond to temperature changes as quickly as it really should.

5. Complete statements about major components of a heating/cooling thermostat. Circle the number in front of the information that best completes each of the following statements.

a. Of the three major components of a thermostat, usually a thermometer and sometimes a manual temperature selector are found in the:

  (1) cover.

  (2) body.

  (3) subbase.

b. The temperature sensing element of a thermostat along with the electrical contacts, usually a heat anticipator, and sometimes a manual temperature selector are found in the:

  (1) cover.

  (2) body.

  (3) subbase.

c. Any manual switches for a thermostat, terminals for wiring connections, and a cooling anticipator, if one is used, are found in the:

   (1) cover.

   (2) body.

   (3) subbase.

d. If they are a single piece, mounting holes and usually guides to mount and level the thermostat will be found in the:

   (1) cover and body.

   (2) body and subbase.

   (3) subbase only.

6. Complete statements about heating thermostat anticipation. Write in the word(s) or information that best completes each of the following statements.

   a. When a heating unit is shut off, some heated air will remain in the unit, and as this air is distributed to the conditioned space, it causes the temperature of the conditioned space to ____________________ the desired setting.

   b. The thermostat must anticipate the amount of _______________ and turn the heating _________ before the temperature of the conditioned space reaches the desired setting.

   c. A heating anticipator is a resistor connected in series with the thermostat contacts, and the resistor ________________ the temperature-sensing element while ________________________is being called for.

   d. The added heat of the resistor causes the thermostat to cease calling for heating approximately _________F before the temperature in the conditioned space reaches the desired setting.

   e. Some heating anticipators, such as in millivolt thermostats, are fixed and preset and some are ________________________ and must be set to match the __________________ ___________________ of the heating control loads activated by the thermostat.

Written Test

7. Complete statements about cooling thermostat anticipation. Write in the word(s) or information that best completes each of the following statements.

   a. When a cooling unit is turned on, it takes some time for the unit to begin producing cool air, and during that time, the conditioned space could become ________________ than the desired setting.

   b. The thermostat must anticipate the need for ______________ in advance and turn on the cooling unit before the temperature of the conditioned space ________________ the desired setting.

   c. A cooling anticipator is a fixed resistor connected parallel to thermostat contacts, and in series with the cooling control loads, and the resistor warms the temperature-sensing element while _____________ is ________ _____________ called for.

   d. The added heat of the resistor causes the thermostat to call for cooling approximately _____F before the temperature in the conditioned space exceeds the desired setting.

8. Identify and solve problems about installing heating/cooling thermostats. Circle the number in front of the statement that best identifies and solves each of the following problems.

   a. A technician installed a thermostat on a wall so close to a nearby door that when the door is left open, the door covers the thermostat. Identify and solve the problem.

      (1) The problem is that air circulation around the thermostat could be blocked. The solution is to move the thermostat to a better position.

      (2) The problem is that air circulation around the thermostat might be interrupted every now and then. The solution is to inform the user to be sure the door is left open.

   b. To make sure that the kids in the family won't tinker with the thermostat, a technician installed the thermostat almost six feet off the floor. Identify and solve the problem.

      (1) The problem is that the thermostat may have been installed a bit too high. The solution is to inform the user to set the thermostat a little lower than normal to compensate for the fact that heat rises.

      (2) The problem is that the thermostat should have been installed four to five feet above the floor. The solution is to reinstall the thermostat at the proper height.

c. A technician installs a thermostat on a sheetrock wall and uses only two screws for the installation. Identify and solve the problem.

(1) The problem is that sheetrock is lightweight enough that two screws may not hold. The solution is to use extra screws.

(2) The problem is that sheetrock is lightweight enough that screws will not properly secure the thermostat. The solution is to use anchors designed for use with sheetrock.

d. While replacing a thermostat that has a mercury bulb electrical contact, a technician carelessly throws the old thermostat into a trash can at a residence. Identify and solve the problem.

(1) The problem is that parts that are replaced should be saved and taken back to the office. The solution is to place the old thermostat in a bag or box and put it in the service vehicle.

(2) The problem is that mercury is toxic. The solution is to place the old thermostat safely in a box and take it back to the office where it can be safely disposed of.

9. Compelete statements about multistage thermostats. Write in the word(s) or information that best completes each of the following statements.

a. Thermostats are often used for more than a single heating and/or cooling function which means that the thermostat must react to more than one ____________________ condition.

b. Thermostats are usually:

(1) single-stage heat or ________________-______________ cooling.

(2) single-stage heat and ________________-_____________ cooling.

(3) ______________-________________ heat and two-stage cooling.

(4) two-stage heat and ______________-_______________ cooling.

(5) two-stage heat and __________-__________ cooling.

c. Two-stage heating or cooling is accomplished with two switches, usually a _______________ bulb on one ____________________.

d. The switches in a two-stage thermostat have a _______F differential between switches.

Written Test

e. In two-stage cooling thermostats, both switches are open at the set temperature; the first stage closes at approximately ______F above the set temperature, and the second stage will close if temperature continues to rise to approximately _____F above the set temperature.

f. In two-stage heating thermostats, both switches are open at the set temperature; the first stage closes at approximately _____F below the set temperature, and the second stage will close if the temperature continues to drop approximately _____F below the set temperature.

g. Two-stage cooling thermostats control two cooling capacities such as a single unit with two ____________________________ or a system with two condensing units.

h. Two-stage heating thermostats control two heating capacities such as a gas furnace with a two-stage gas valve, an electric furnace with staged heating elements, or a _____________ __________________ with supplementary heat.

10. Complete statements about subbase applications. Write in the word(s) or information that best completes each of the following statements.

a. Thermostats and subbases must be _________________________ and ____________________ to match the specific application.

b. A thermostat should be selected primarily for the number of _______________ of heating and/or cooling that have to be controlled.

c. A thermostat can usually be matched with ______________________ _________________ subbases.

d. A subbase should be selected not only for the number of stages, but for desired additional functions such as ___________ control, auxiliary valve or ____________ control, or heat pump ____________________valve control.

e. Subbase ___________________ must be connected to the proper stages or controls.

f. Common thermostat subbase terminal markings and what they connect to are:

(1) V or ____ - power from transformer.

(2) F or ____ - fan control.

(3) H or ____ - heating, single-stage or first-stage.

Written Test

(4) C or ____ - cooling, single-stage or first-stage.

(5) ____ - auxiliary heating control.

(6) ____ - auxiliary cooling control.

g. Most thermostat manufacturers use R, G, W, Y, B, and O because they represent the colors red, green, white, yellow, blue, and orange which enables the installer to ______________ ____________ the control wiring more easily.

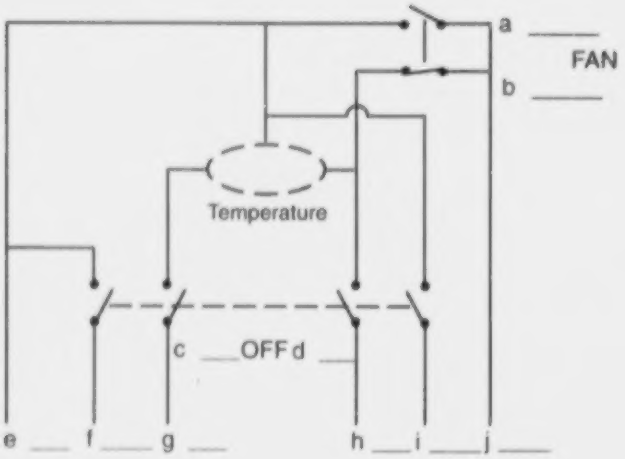
h. Thermostat wire usually comes in a sheathed cable with from two to ten conductors with color-coded ______________________.

i. Multistage thermostats often use subscripts along with the standard letter coding to designate terminals for each stage; ______or ______ for first stage heating, and ______ or _____ for second stage heating.

j. On systems that use separate control power transformers, the subbase used must have an ______ terminal for the heating system power, and an _______ terminal for the cooling system power.

k. When a subbase for a system that uses separate control power transformers is used on a system with only one transformer, the ______ and _______ terminals must be connected together.

11. Match basic internal thermostat switching with controls and external wiring. Place the number beside the control or wiring in the blank showing its location.



1. Y
2. R
3. HEAT
4. B
5. ON
6. W
7. G
8. AUTO
9. O
10. COOL

Written Test

12. Identify and solve problems about programmable thermostat applications. Circle the number in front of the statement that best solves each of the following problems.

    a. A technician programming an electronic thermostat for summer operation sets the thermostat back from 68°F to 60°F. Identify and solve the problem.

        (1) The problem is that the thermostat was set back too far. The solution is to set the thermostat back to only 66°F.

        (2) The problem is that the techician made a setting for winter operations. The solution is to set the thermostat up from 68°F to 74° or 76°F.

    b. A technician programming an electronic thermostat for winter operations at a business sets the thermostat back from 68°F to 60°F, and times the setback for 10 p.m. Identify and solve the problem.

        (1) The problem is that the setback for a business space can be greater than the setback for a residence. The solution is to set the thermostat back from 68°F to 60°F.

        (2) The problem is that the setback for a business space can be greater than the setback for a residence, and the setback can be for a longer period. The solution is to set the thermostat back from 68°F to 50°F, and time the setback start time for 5 p.m.

13. Select true statements about electronic thermostat characteristics. Place an "X" beside each true statement.

    ___ a. An electronic solid-state thermostat uses a small microprocessor to perform many of the functions which are accomplished with electromechanical parts in a standard thermostat.

    ___ b. Sensing temperatures, anticipation, cycling rate, and selection of temperature set points are all accomplished electronically.

    ___ c. Electronic thermostats use an LED, digital display to show such things as current time and temperature, setup or setback time and temperature, and some show humidity levels, display reminders when to change the filter, and show outdoor temperatures.

    ___ d. In addition to the standard thermostat components such as subbase and system switches, the electronic thermostat includes a battery to provide power to retain the microprocessor memory anytime voltage is not available to the thermostat.

Written Test

__ e. Electronic thermostats mount like a standard thermostat, but they must be mounted level, not only for appearance but because of electronic circuitry components.

__ f. Always disconnect power when mounting a thermostat.

__ g. Even though electronic thermostats use solid-state circuitry, most of the components can be serviced in the field.

__ h. Always check the OEM installation and programming instructions before installing or servicing an electronic thermostat.

14. Select true statements about the additional benefits of solid-state thermostats. Place an "X" beside each true statement.

__ a. In addition to performing the functions of electromechanical models, the solid-state thermostat can do many things that were previously not possible.

__ b. The operation and service of comfort systems has been revolutionized by the capacity of microprocessors to collect and act on large amounts of information.

__ c. The latest models of programmable thermostats not only change the temperature settings at preset times, but can anticipate when to change the settings based on the unit warm-up and cool-down characteristics and the outdoor temperature.

__ d. Thanks to the capability of the microprocessor to differentiate between stages and to compare unit capacity with heating demand, setback thermostats for heat pumps are also available.

__ e. On some models, the technician can use a prescribed procedure to cause a microprocessor based control center to run the system through an abbreviated version of its complete operating cycle.

__ f. Other models will automatically test the complete system by collecting information from every part of the system and comparing actual system operations with a programmed model of how the system should be operating.

__ g. Troubleshooting solid-state thermostats takes special skills, but the improved performance is worth the extra procedures a technician has to learn.

__ h. The microprocessor has made it possible for controls on systems of any size to evaluate a wide range of variables affecting both comfort control and energy management.

Written Test

15. Complete statements about special applications of line voltage thermostats. Circle the number in front of the information that best completes each of the following statements.

    a. Line voltage thermostats are used on:

        (1) heavy commercial air conditioning equipment and residential heat pump systems.

        (2) room air conditioners, domestic refrigerators and freezers, and many commercial refrigeration units.

    b. The range adjustment on a line voltage thermostat:

        (1) is used to adjust the maximum and minimum operating temperature settings, and can be done by a user.

        (2) is used to adjust cut-in, cut-out settings, and should be done by a qualified technician.

    c. The two screws on the back or side of a line voltage thermostat indicate:

        (1) A fixed differential that cannot be changed.

        (2) An adjustable differential that should be adjusted only by a qualified technician.

Permission to duplicate this test is granted.

Thermostats
Unit 7

Unit Evauation Form

Student Name_________________________ Date ________Unit Rating______

Job Sheet 1–Install a Wall Thermostat and Determine Heat Anticipation Comments:	Rating ______
Job Sheet 2–Replace a Thermostat With an Electronic Programmable Thermostat Comments:	Rating ______
Job Sheet 3–Program a Programmable Thermostat Comments:	Rating ______
Other:	
Written Tests: Pretest ______	Posttest _______ total _______
Student Signature ____	Date
Teacher Signature ____	Date

Permission to duplicate this form is granted.

Introduction to Electric Motors
Unit 8

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan enrichment of exceptional students as well as accommodation of special needs students.

4. Add overheads or other graphic materials as desired to enhance instruction.

5. Develop teaching plan. Adjust for different learning styles.

6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.

8. Discuss unit and specific objectives.

9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.

10. Discuss the student supplement. Explain to students how you plan to evaluate the supplement, if at all.

11. Discuss the assignment sheets and their evaluation criteria.

12. Discuss and demonstrate the procedures in the job sheets. Review criteria for evaluating these activities.

Evaluation

13. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

14. Make copies of written test. Add or modify test items as needed.

15. Give written test.

Suggested Activities

16. Compile assignment and job sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets added to the unit.

17. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: a SCANS Report for America 2000.* These SCANS skills and competencies have been adapted by MAVCC to help instructors and program planners effectively articulate curriculum.

1. Appoint student teams and have each team find at least three types of motors as discussed in Objective 3. Have each team select a leader to report on their findings, and have them emphasize the "special" nature of each motor application. **Interpersonal skills, teamwork.**

2. Show students parts of old DC and AC motors as you discuss Objectives 4 and 5. Use the parts to reinforce the similarity of DC, AC motor operations. **Basic skills, science and listening.**

3. Find a system in your own shop or at your school so you can show students an electronically commutated motor application as discussed in Objective 7. **Basic skills, science and listening.**

Resources Used in Developing This Unit

1. Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.

2. *The Air Conditioning, Heating and Refrigeration News HVAC/R Source Guide.* Troy, MI: Business News Publishing Company, 1995.

3. Wantiez, Gary W. *ACR Electrical Components and Systems.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.

4. Smreker, Eugene and King Calvert. *Major Appliance Repair.* Stillwater, OK: The Mid- America Vocational Curriculum Consortium, 1987.

Suggested Activities

Suggested Supplemental Resources

T. B. Wood's Incorporated publishes an excellent V-belt service guide. From selection to troubleshooting *Installation and Maintenance of V-Belt Drives* covers all V-belt service areas.

1: Inspection and Maintenance
2: Belt Selection
3: Safety Tips
4: Drive Installation
5: Tensioning the Drive
6: Troubleshooting V-Belts

The V-belt is industry's most popular means of power transmission and an important area of expertise for ACR technicians. The guide is well illustrated and concludes with an extensive troubleshooting section with photos of types of improper belt wear and a discussion of what causes improper belt wear and how to prevent it.

For a copy of the guide, call 1-800-789-6637, FAX your request to 717-264-6420, or write:

T.B. Wood's Incorporated
440 North Fifth Avenue
Chambersburg, PA 17201

Through the Office of Energy Efficiency and Renewable Energy, the U.S. Department of Energy has instituted a **Motor Challenge Program** dedicated to energy conservation through motor design improvement and enhanced applications. Varied types of industrial firms have partnerships in the program, but anyone interested in motors is welcome to a free partnership. A partnership entitles participants to literature about motor improvements as well as improvements in drives, fans, pumps, blowers, and compressors.

For information about the Motor Challenge Program, call **1-800-862-2086**, or access the program on the World Wide Web: **http://www.motor.doe.gov**.

Suggested Activities

Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Option A

4—Can perform job with no additional training.
3—Moderately skilled—Has performed job during training program; limited additional training may be required.
2—Limited skill—Has performed job during training program; additional training is required to develop skill.
1—Unskilled—Is familiar with process but is unable to perform job.

Option B

Yes—Can perform job with no additional training.
No—Is unable to perform job.

Introduction to Electric Motors
Unit 8

Answers to Assignment Sheets

Assignment Sheet 1

A. 5"
B. 8"
C. 4"

Assignment Sheet 2

Note: Answers may vary, but must include the following items for each scenario.

A. (1) Reset breaker.

(2) Check start and run amps and compare them to name plate ratings.

B. (1) Clean motor.

(2) Check start and run amps and compare them to name plate ratings.

C. (1) Replace bearings or motor.

(2) Check start and run amps and compare them to name plate ratings.

D. (1) Adjust belt to proper tension.

(2) Check start and run amps and compare them to name plate ratings.

E. (1) Check belt tension.

(2) Adjust belt tension, if necessary.

(3) Check start and run amps and compare them to name plate ratings.

(4) Check to see if run amps are still in excess of name plate rating.

(5) If necessary, reduce load or use larger motor.

Introduction to Electric Motors
Unit 8

Answers to Written Test

1. a. 4
   b. 8
   c. 9
   d. 7
   e. 1
   f. 5
   g. 3
   h. 2
   i. 6

2. a, d, e, f

3. a. (1) Shaded-pole or split-phase
      (2) Split-phase or shaded-pole
      (3) Capacitor, induction, capacitor
      (4) permanent split capacitor
      (5) capacitor, capacitor
   b. three-phase
   c. electronically commutated
4. a. (2)
   b. (2)

5. a, b, c, d, e, f, g, h

6. a. power
   b. attracting
   c. magnetic attraction
   d. magnetic attraction
   e. lead, flow ahead
   f. leading, lagging
   g. splitting
   h. torque

7. a, b, e, f, g, h, i

8. a. 5
   b. 9
   c. 12
   d. 2
   e. 3
   f. 14
   g. 1
   h. 4
   i. 7
   j. 10
   k. 8
   l. 13
   m. 11
   n. 6

Answers to Written Test

9. a, b, c, e, f

10. a. 5
    b. 3
    c. 1
    d. 4
    e. 2

11. a. application
    b. stamped
    c. (1) equipment
        (2) number
        (3) type
        (6) coded
        (11) rated load
        (14) Celsius, °C
        (15) heavy
        (17) NEMA
        (18) arrow

12. b, c, d, e

13. a. (1)
    b. (1)
    c. (2)

14. a. (2)
    b. (1)
    c. (2)
    d. (2)

15. a. (1)
    b. (2)
    c. (2)

Introduction to Electric Motors
Unit 8

Written Test

Name____________________________________Date________Score______

1. Match each term on the right with its correct definition.

__ a. That part of a motor or generator that has coils of wire wrapped around a metal core so that current can be induced to produce torque in the motor

__ b. A substance applied to pulley belts to reduce noise and increase friction

__ c. The degree of movement that indicates belt tension between two pulleys when the belt is depressed at or near a center point between the pulleys

__ d. Insulated wire wound around a soft iron core which becomes a magnet when current flows through the wire

__ e. The National Electrical Manufacturer's Association, a group that establishes standards for electric motors

__ f. The laminated, soft iron elements of a stator which have insulated wire wrapped around them to form the main windings in a motor

__ g. A rotating permanent magnet in an AC motor

__ h. A stationary electromagnet in an AC motor

__ i. Amount of turning capacity

1. NEMA
2. Stator
3. Rotor
4. Armature
5. Poles
6. Torque
7. Electromagnet
8. Belt dressing
9. Deflection

2. Select true statements about electric motor applications. Place an "X" beside each true statement.

__ a. Motors used for different applications require motors with different characteristics; small propeller fan motors are required to do quite different things than large refrigerant compressor motors.

__ b. The motor starting a compressor must have medium torque to be able to start against a medium load while a fan motor requires high torque so it can start fast.

Written Test

__ c. Since a motor with high torque is more expensive than a motor with low torque, the motor selected for a given job will be the one with the most torque so it will not have to use as much energy to get the job done.

__ d. Larger motors, particularly in commercial or industrial applications use three-phase, 3 Ø, power to achieve required torque.

__ e. Almost all smaller motors use different applications of single-phase, 1 Ø, power to achieve required torque.

__ f. An ACR technician must not only be able to identify the different types of motors, but must be able to select the most appropriate motor for a specific application.

3. Complete statements about types of electric motors. Write in the information that best completes each of the following statements.

   a. Types of single-phase AC motors used in ACR equipment include:

      (1) ____________-________________.

      (2) ____________-________________.

      (3) ______________________ start, ____________________ run, CSIR, often referred to as simply ________________________ start or CS.

      (4) __________________ _______________ __________________, PSC.

      (5) _____________________ start, ______________________ run, CSR.

   b. There is only one basic type of _____________-_____________ AC motor.

   c. ______________________________ ______________________________ motors, ECMs, are DC motors used to provide variable speed operations.

4. Identify and solve problems about basic DC motor operation. Circle the number in front of the statement that best identifies and solves each of the following problems.

   a. A technician with whom you are working tells you that DC motors are pretty common in ACR applications. Identify the problem and select the best solution.

      (1) The problem is that DC motors are not in common use in ACR applications; the solution is for the technician to remember that DC motors are in no way like AC motors.

(2) The problem is that most motors used in ACR applications are AC motors; the solution is to remember that examining DC motor principles is a good way to start learning about AC motors.

b. While discussing DC motor operation, two technicians argue about their operation; the first technician says they work the same as AC motors, the second technician says they work because DC power creates a special kind of magnetic field. Identify the problem and select the best solution.

(1) The problem is that both technicians are wrong; the solution is to remember that DC and AC motors are only similar because they both use a form of electricity to operate.

(2) The problem is that the first technician is totally wrong and the second technician is only partially right. The solution is to note that applying DC power causes the armature in a DC motor to become an electromagnet which turns because of the attraction/repulsion principle that works with the N,S orientation of the armature and the N,S poles of the fixed magnets in the motor.

5. Select true statements about AC motor operation. Place an "X" beside each true statement.

__ a. An AC induction motor, like a DC motor, has both a coil and a permanent magnetic field.

__ b. In a DC motor the permanent magnet is stationary and the coil rotates, but in an AC motor the coil is stationary and the permanent magnet rotates.

__ c. In an AC induction motor, the coil and an iron core form a stationary electromagnet called a stator.

__ d. The permanent magnet and the shaft it is mounted on form a rotor which rotates within the stator.

__ e. Since alternating current reverses direction of flow 120 times a second on 60Hz current, the electromagnetic poles of the stator reverse polarity 120 times a second.

__ f. The stator poles alternately attract and repel the permanent magnetic poles of the rotor as the N and S poles of the stator reverse polarity.

__ g. The magnetic fields created by winding wires of different sizes and resistance onto the poles within the stator produce torque which causes the motor to start and continue spinning.

Written Test

___ h. The windings in an induction motor are either high resistance start windings or low resistance run windings.

6. Complete statements about single-phase AC motor starting. Write in the information that best completes each of the following statements.

   a. Once a single-phase motor starts, it will run as long as ________________ is applied to the motor, but once it stops, something must be done to get it started.

   b. In a motor with only one stator pole, the rotor will stop with the N and S poles __________________________ each other, and without any assistance, the motor will not start again.

   c. Adding another stator pole to the motor would appear to solve the problem by providing _________________ ____________________ to deflect the rotor and start rotation.

   d. If the rotor stops equidistant between two stator poles, equal ____________________ ______________________ by the two poles will once again make the motor unable to start.

   e. The problem of making the motor start can be solved by using a method to make the current around one pole _____________ or _____________ _____________ of the current around the other pole.

   f. When AC power is applied, the pole with the __________________ current will have a stronger attraction than the pole with the ____________________ current and rotation will start.

   g. Different types of motors use various methods of ______________________ the phase or creating two-phase current.

   h. The amount of turning ability created by the phase split is called ______________ and is the basic difference between all single-phase motors used in ACR applications.

7. Select true statements about electronically commutated motors. Place an "X" beside each true statement.

   ___ a. Electronically commutated motors, ECMs, are brushless DC motors which enable variable speed motor operations such as fans and blowers, and variable volume controls such as refrigerant metering devices.

Written Test

__ b. Power for ECMs begins with 1Ø AC voltage which is filtered in the electromagnetic interference, EMI, module which also prevents feedback which could interfere with household electronic devices such as stereos and TVs.

__ c. The filtered AC current is converted to rectified DC by a transformer.

__ d. Rectified DC is smoothed out by a relay placed across the line.

__ e. An ECM drive unit converts the DC voltage to a three-phase square-wave voltage and applies it sequentially to the three-phase stator windings in the motor.

__ f. In an ECM, like in an AC motor, the armature is permanently magnetized which produces a magnetic interaction opposite to that in a standard DC motor.

__ g. The ECM drive unit reverses the magnetic field electronically instead of using a brush and commutator arrangement which eliminates brushes and commutators and their disadvantages.

__ h. An ECM operates similar to a three-phase motor; the frequency of the ECM drive signal determines motor speed while current level determines the motor torque.

__ i. A microprocessor signal tells the ECM drive unit at what speed to run the motor by the frequency of the pulses it sends.

Written Test

8. Match basic AC electric motor parts with their functions. Place the number beside the motor part in the blank beside the statement that defines its function.

___ a. The housing or body of the motor which contains the stator

___ b. The iron core and coil of wire wound around it that form the stationary electromagnet

___ c. The coil of wire in the stator

___ d. An electrical protection device built into the motor to protect against high temperatures and high current

___ e. Parts that contain the bearings and fasten to each end of the frame

___ f. Round parts in the center of an end bell which fit around the shaft and allow the shaft to turn with minimal friction

___ g. A bearing which uses a solid metal sleeve designed to allow oil to flow from the wick to lubricate the shaft

___ h. A bearing which uses multiple metal balls and grease and is usually permanently prelubricated

___ i. An absorbant material designed to hold lubricating oil around a sleeve bearing

___ j. A permanent magnet which is mounted on a shaft, fits into the stator, and rotates

___ k. Vane-like pieces fastened to the end of the rotor to circulate air which helps cool the motor

___ l. A metal rod which fits through the center of the rotor, rotates, and transfers the rotation to such things as blowers and pumps

___ m. Spacers on the shaft which are used to center the rotor within the stator

___ n. Bolts that fit through the end bells and frame and hold the entire motor together

1. Sleeve bearing
2. Overload
3. End bells
4. Ball bearing
5. Frame
6. Assembly bolts
7. Wick
8. Fans
9. Stator
10. Rotor
11. Thrust washers
12. Winding
13. Shaft
14. Bearings

Written Test

9. Select true statements about types of motor construction. Place an "X" beside each true statement.

   __ a. Motors are constructed for service in different applications and environments.

   __ b. Open motors have air openings in the frame and/or ends and are used where dirt, dust, and moisture are not a problem.

   __ c. Open drip-proof motors have air openings in the frame with shrouds to prevent moisture from entering and are used where dripping moisture may be a problem.

   __ d. Totally enclosed motors, not sealed, have minimal air openings and are used where dust, dirt, or moisture might be a problem.

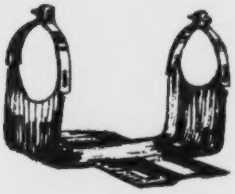
   __ e. Explosion proof motors are constructed so that no sparking occurs and are used where explosive vapors are a problem.

   __ f. Submersible motors are totally enclosed and sealed and are used where it is necessary for the motor to be submersed in water or some other fluid.

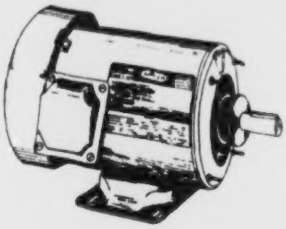
   __ g. A motor may be a single type, but it will never be a combination type.

10. Identify types of motor mounts and their typical applications. Place the number beside the motor mount in the blank beside the description of its application.

   __ a. Used on belt-drive blowers and window air conditioners



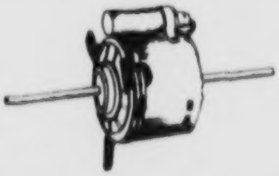
   __ b. Used on large belt-drive applications



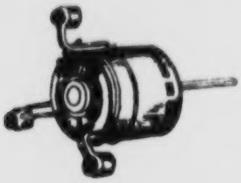
220

Written Test

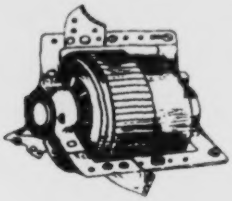
__ c. Used on window air conditioners



__ d. Used on direct-drive blowers and window air conditioners



__ e. Used on direct-drive blowers



1. Lug-ring
2. Blower frame
3. Rigid
4. Three-ring
5. Cradle

11. Complete statements about motor data plates. Write in the information that best completes each of the following statements.

    a. Most electric motors have information about the motor and its ______________________ somewhere on the motor.

    b. Motor information usually is on a paper label or metal data plate although occasionally the information is ______________ directly somewhere on the motor itself.

    c. Information provided on a typical motor data plate may include:

        (1) the manufacturer's name, which may include the manufacturer of the ______________________ and the manufacturer of the motor,

Written Test

(2) manufacturer's ____________________, which may mean different things depending on the manufacturer,

(3) ____________ of motor such as split-phase, shaded-pole, or other,

(4) model number,

(5) serial number,

(6) type, which is a _______________ designation using numbers or letters to indicate such things as type of motor and type of enclosure,

(7) horsepower rating, Hp,

(8) voltage,

(9) phase, Ph,

(10) hertz (cycle),

(11) full load amperage, F.L.A., sometimes called ______________ _____________ amperage or R.L.A.,

(12) locked rotor amperage, L.R.A.,

(13) revolutions per minutes, RPM, that a motor shaft turns,

(14) temperature rise, which is the allowable motor temperature increase and is usually indicated in degrees __________________, ________,

(15) duty rating such as light, _________________, continuous,

(16) service factor, S.F.,

(17) frame, which is a _________________ designated number indicating the size of the body of the motor, and

(18) rotation which is normally designated by an ________________ or CW for clockwise or CCW for counterclockwise.

Written Test

12. Select true statements about pulleys and belts. Place an "X" beside each true statement.

Note: For a statement to be true, all parts of the statement must be true.

__ a. Most motor applications are belt drive with V-pulleys and a belt connecting the motor shaft to the load.

__ b. V-pulleys, also called sheaves, come in three types:

(1) standard pulleys with a single nonadjustable groove.

(2) step pulleys, which are like several standard pulleys fastened together.

(3) adjustable pulleys, which can be adjusted to change the diameter of the pulley and/or the width of the groove.

__ c. A pulley on a motor is connected to a pulley on a load such as a blower by a V-belt which wraps around both pulleys.

__ d. The length of a V-belt is the distance around the outside of the belt, and the width is also measured at the outside, which is the widest part of the belt.

__ e. It is important to select the proper belt and pulleys for each specific application and to adjust the belt for the proper tension and alignment.

13.

Complete statements about pulley selection. In the following scenarios, circle the number in front of the information that makes each of the following statements true.

a. When using a pulley selection chart, it is most important to:

(1) match the RPM of the motor.

(2) match the desired CFM of the load.

b. If a pulley selection chart is not available, use the following pulley selection formula:

(1) RPM of motor pulley x diameter of motor pulley = RPM of equipment pulley x diameter of equipment pulley.

(2) RPM of motor pulley ÷ 1725 = RPM of equipment pulley x diameter of equipment pulley.

c. Standard pulleys are normally available in increments of:

(1) 1/8"

(2) 1/4"

14. Complete statements about sizing and selecting V-belts. Circle the number in front of the item that best completes each of the following statements.

a. The first step in selecting a V-belt is to determine:

(1) the length of the belt needed.

(2) the width of the belt needed.

b. The next step in selecting a V-belt is to determine:

(1) the length of the belt needed.

(2) the width of the belt needed.

c. The numbers and letters on a V-belt indicate the size of the belt, but only:

(1) for V-belts less than 1" wide and less than 4' long.

(2) if you know how to interpret the numbers and letters.

d. The final step in selecting a V-belt is to:

(1) select an industrial quality belt to be sure of good service.

(2) select a belt designed for the type of duty the belt will be subjected to.

15. Solve problems about troubleshooting electric motors. Circle the number of the statement that best solves each of the following problems.

a. A coworker troubleshooting a motor says all motors are basically the same and troubleshooting is basically the same.

(1) The problem is that all motors are not the same and that good troubleshooting requires knowledge of how a motor is supposed to respond, information gained through your own experience or by referencing a good troubleshooting guide.

(2) The problem is that motors are not the same because small motors usually require only mechanical troubleshooting.

b. A coworker troubleshooting a motor says that simply looking at a motor is the best way to determine if there is a mechanical problem.

(1) The problem is that electrical test instruments are often the best way to spot mechanical problems.

(2) The problem is that checking for a mechanical problem means more than just looking at a motor; it means listening for unusual noises and even physically manipulating the motor while looking and listening.

c. All motor troubleshooting activity should conclude with:

(1) a final check with a voltmeter to make sure the correct voltage is available to the motor.

(2) checking the start and run amps and comparing them with the data plate ratings.

Permission to duplicate this test is granted.

Introduction to Electric Motors
Unit 8

Unit Evaluation Form

Student Name____________________________Date_______Unit Rating________

Assignment Sheet 1—Use a Pulley Selection Chart Rating_____

Comments:

Assignment Sheet 2—Solve Electric Motor Problems Rating_____

Comments:

Job Sheet 1—Replace a Missing V-Belt, Adjust Tension, and Check Motor Operation Rating_____

Comments:

Other:

Written Test__________ Pretest____________ Posttest___________

Total__________

Teacher Signature__________________________________ Date__________

Student Signature__________________________________ Date__________

Permission to duplicate this form is granted.

Shaded-Pole Motors
Unit 9

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan enrichment of exceptional students as well as accommodation of special needs students.
4. Add overheads or other graphic materials as desired to enhance instruction.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss and demonstrate the procedures in the job sheets. Review criteria for evaluating these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of written test. Add or modify test items as needed.
13. Give written test.
14. Compile job sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets added to the unit.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified in What Work Requires of Schools: a SCANS Report for America 2000. These SCANS skills and competencies have been adapted by MAVCC to help instructors and program planners effectively articulate curriculum.

1. Have several different shaded-pole motors on hand as students begin discussing Objective 2. Help establish for students that these are small motors manufactured for special applications. **Basic skills, science and listening**.

2. Try to assemble a shaded-pole motor selection that will include two-pole, four-pole, and six-pole motors and explain to students how the poles and RPMs are related and the special applications these motors accomplish. **Basic skills, science and listening**.

3. Demonstrate the tapped winding and reactor used to accomplish varying motor speeds in shaded-pole motors. **Basic skills, science and listening**.

4. Prepare students for activities in Job Sheet 1 by demonstrating motor rotation as it is presented in Objective 5. **Basic skills, reading and listening**.

5. Assign students to small groups and have members of each group look for applications in their homes or apartments where shaded-pole motors are being used. Have each group member present findings to the class and discuss why shaded-pole motors were probably selected for the applications students found. **Interpersonal skills, team work; basic skills, science and speaking.**

Resources Used in Developing This Unit

1. Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning*. South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.

2. *The Air Conditioning, Heating and Refrigeration News HVAC/R Source Guide*. Troy, MI: Business News Publishing Company, 1995.

3. Wantiez, Gary W. *ACR Electrical Components and Systems*. Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.

4. Smreker, Eugene and King Calvert. *Major Appliance Repair*. Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1987.

Suggested Activities

Suggested Supplemental Resources

In their general training series, Carrier Training Services has several modules dedicated to the electrical elements of ACR training. Their are nine modules in their basic series, including *Module 7, Motor Fundamentals and Motor Protection.* Other modules range from introduction to electricity to electrical troubleshooting. The well executed series is enhanced with full color graphics and includes VHS videos, audio cassettes, and student workbooks. Quantity discounts are available for vo-tech schools and other training institutions. For a catalog of these and other materials from Carrier Training Services, write to:

Literature Services, Bldg. TR-8
P.O. Box 4808
Syracuse, NY 13221

Honeywell's *Principles of Motor Operation* is an excellent reference to supplement training for both beginning and advanced HVACR students. The material is one of Honeywell's programmed instruction books built around a step-by-step, question-answer format. Topics include: nature of electricity; rules governing electricity; inductive and capacitive circuits; fundamentals of residential controls; power, transformer principles; relay principles; and analyzing control circuits. The Honeywell product number for this impressive 250-page workbook is 71-97083. Check with your local Honeywell distributor or call Honeywell at 1-800-345-6770. ext. 2040. You may also access the Honeywell website at **http://www.honeywell.com/controls.html**.

Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Suggested Activities

Option A

4—Can perform job with no additional training
3—Moderately skilled—Has performed job during training program; limited additional training may be required.
2—Limited skill—Has performed job during training program; additional training is required to develop skill.
1—Unskilled—Is familiar with process but is unable to perform job.

Option B

Yes—Can perform job with no additional training.
No—Is unable to perform job.

Shaded-Pole Motors
Unit 9

Answers to Written Test

1. a. reactor
   b. shading

2. a. low
   b. dual
   c. efficient
   d. (1) evaporator or condenser
      (2) condenser or evaporator
      (3) small
      (4) small
      (5) furnace

3. a. phase split
   b. phase split
   c. shading coil
   d. closed
   e. winding
   f. (1) two
      (2) four
      (3) six
   g. speed

4. a. (2)
   b. (2)

5. a, b, d

6. a (2)
   b. (1)
   c. (4)
   d. (2)
   e. (2)

7. a. .36A
   b. 38W

Shaded-Pole Motors
Unit 9

Written Test

Name ________________________________ Date ____________ Score _______

1. Complete statements about terms and definitions for shaded-pole motors. Write in the term that completes each of the following definitions.

    a. A coil of many turns of fine wire which is wired in series with the stator of a shaded-pole motor to provide a lower speed is a _________________ coil.

    b. A closed loop of wire placed in a slot in the stator pole of a shaded-pole motor to provide a phase shift to aid in motor starting and to determine direction of rotation is a ___________________ coil.

2. Complete statements about characteristics and applications of shaded-pole motors. Write in the information that best completes each of the following statements.

    a. Shaded-pole motors are small, inexpensive, single-phase motors with ________ torque.

    b. Shaded-pole motors come in either 120 VAC or 208/240 VAC, but not in either ____________ or three-phase voltages.

    c. Shaded-pole motors are not as __________________________ as most other types of motors, but their low cost makes them a good choice for many low torque applications.

    d. Shaded-pole motors are used in such applications as:

        (1) refrigerator ____________________________ fans,

        (2) refrigerator ____________________________ fans,

        (3) _______________ window air conditioner fans,

        (4) _______________ furnace blowers,

        (5) ________________ combustion fans, and

        (6) timers.

3. Complete statements about shaded-pole motor construction. Write in the information that best completes each of the following statements.

    a. Like all single-phase motors, shaded-pole motors must create a _____________ ____________ which produces the two-phase current required to start the motor.

Written Test

b. Shaded-pole motors accomplish the ______________ ______________ by using a shading coil.

c. A ______________ ______________ is a portion of the stator winding wrapped around a separate portion of the laminated stator pole.

d. Each shading coil is a ____________ loop of wire wrapped through a slot in the stator pole.

e. The shading coil is located between the stator ______________ and the rotor.

f. The motor RPM is determined by the number of stator poles:

   (1) __________ pole, 3,000 RPM,

   (2) __________ pole, 1,500 RPM, and

   (3) __________ pole, 1,050 to 1,100 RPM.

g. The ______________ of a shaded-pole motor may vary over a wide range with a change in either the load or the applied voltage.

4. Select true statements about controlling shaded-pole motor speed. Circle the number in front of the information that makes each of the following statements true.

   a. When a tapped winding is used to accomplish a speed change in a shaded-pole motor:

      (1) a modified hard-start kit provides the required adjusted voltages.

      (2) the complete winding high resistance is used for low speed and a portion of the winding is used for each higher speed.

   b. When a reactor coil is used to accomplish a speed change in a shaded-pole motor:

      (1) the main winding is tapped on each end.

      (2) the stator winding produces a slower speed than using the winding without the reactor coil.

5. Select true statements about shaded-pole motor rotation. Place an "X" beside each true statement.

   __a. Shaded-pole motor rotation is determined by which side of the stator pole the shading slot is cut in.

   __b. Since it is not practical to change the location of slots in the stator pole, rotation cannot be changed unless electrical rotation reversal characteristics were built into the motor at the time of manufacture.

__c. Electrical reversal of rotation can be accomplished by simply reversing the leads to the motor.

__d. Direction of rotation is determined by which set of leads are connected.

6. Select true statements about troubleshooting shaded-pole motors. Circle the number in front of the information that makes each of the following statements true.

   a. Since most shaded-pole motors are small, time-consuming to disassemble, and relatively inexpensive, the generally accepted troubleshooting procedure is to:

      (1) repair only motors that have minor problems.

      (2) replace rather than repair a shaded-pole motor that is having problems.

   b. Some shaded-pole motors are large enough to disassemble and clean or:

      (1) make minor repairs such as bearing replacement.

      (2) make major repairs including rewinding the motor.

   c. Shaded-pole motors should be checked for:

      (1) cleanliness
      (2) shaft play
      (3) operation within design parameters
      (4) all of the above

   d. Many small motors are rated in:

      (1) L.R.A. instead of F.L.A.

      (2) full load watts instead of full load amps.

   e. If a motor is clean, has no bearing problems, is receiving proper voltage, and still will not run or draws too much amperage:

      (1) the motor is probably okay and merits repair.

      (2) the motor should probably be replaced with a new motor.

Written Test

7. Solve problems using the power factor for watt/amp amp/watt conversions.

Note: Round off answers to two decimal places.

a. Given a 120 VAC motor with a name plate rating of 30W, convert the wattage to the expected amp draw of the motor when you know the Pf is .70.

Note: Be sure to show your calculations and remember to modify watts law to read P = I x E x Pf.

Answer___________

b. Given a 120 VAC motor with a name plate rating of 35W, convert a measured amp draw of .40A to watts when you know the Pf is .80.

Answer__________

Permission to duplicate this test is granted.

Shaded-Pole Motors
Unit 9

Unit Evaluation Form

Student Name ______________________________ Unit Rating ________

Job Sheet 1—Wire a Shaded-Pole Motor to a Voltage Supply Rating _____

Comments:

Job Sheet 2—Disassemble, Inspect, Clean, Reassemble, and Check Operations of a Shaded-Pole Motor Rating _____

Comments:

Other:

Written Test __________ Pretest __________ Posttest __________

Total __________

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

Permission to duplicate this form is granted.

Split-Phase Motors
Unit 10

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to dedtermine the order in which you will present the objectives.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan enrichment of exceptional students as well as accommodation of special needs students.

4. Add overheads or other graphic materials as desired to enhance instruction.

5. Develop teaching plan. Adjust for different learning styles.

6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.

8. Discuss unit and specific objectives.

9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.

10. Discuss and demonstrate the procedures in the job sheets. Review criteria for evaluating these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

12. Make copies of written test. Add or modify test items as needed.

13. Give written test.

14. Compile job sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets added to the unit.

15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: a SCANS Report for America 2000*. These SCANS skills and competencies have been adapted by MAVCC to help instructors and program planners effectively articulate curriculum.

1. Have several different split-phase motors on hand as students begin discussing Objective 2. Help establish for students why these motors are different from shaded-pole motors and what applications they are especially suitable for. **Basic skills, science and listening.**

2. Try to assemble a split-phase motor selection that will allow students to get an idea of motor size in relation to application. **Basic skills, science and listening.**

3. Disassemble motors as needed to demonstrate the motor construction elements presented in Objective 3. Impress upon students the important concepts behind the designs for start and run windings in split-phase motor construction. **Basic skills, science and listening.**

4. Discuss and demonstrate starting mechanisms as outlined in Objective 4, and have on hand a hermetic motor to show external start mechanisms. **Basic skills, science and listening.**

5. Prepare students for activities in the job sheets by demonstrating wiring connections as presented in Objective 5. **Basic skills, reading and listening.**

6. Assign students to small groups and have members of each group look for applications of split-phase motors in their own homes or apartments or in businesses where they know the owner. Have each group member present findings to the class and discuss why split-phase motors were probably selected for the applications students found. **Interpersonal skills, team work; basic skills, science and speaking.**

Resources Used in Developing This Unit

1. Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning*. South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.

2. *The Air Conditioning, Heating and Refrigeration News HVAC/R Source Guide*. Troy, MI: Business News Publishing Company, 1995.

3. Wantiez, Gary W. *ACR Electrical Components and Systems*. Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.

4. Smreker, Eugene and King Calvert. *Major Appliance Repair*. Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1987.

Suggested Activities

Suggested Supplemental Resources

In their general training series, Carrier Training Services has several modules dedicated to the electrical elements of ACR training. Their are nine modules in their basic series, including *Module 7, Motor Fundamentals and Motor Protection.* Other modules range from introduction to electricity to electrical troubleshooting. The well executed series is enhanced with full color graphics and includes VHS videos, audio cassettes, and student workbooks. Quantity discounts are available for vo-tech schools and other training institutions. For a catalog of these and other materials from Carrier Training Services, write to:

Literature Services, Bldg. TR-8
P.O. Box 4808
Syracuse, NY 13221

"Principles of Motor Operation" is one topic presented in Honeywell's *Fundamentals of Residential Controls.* The inexpensive text ($9.00) is one of Honeywell's programmed instruction books built around a step-by-step, question-answer format. Other topics include: nature of electricity; rules governing electricity; inductive and capacitive circuits; fundamentals of residential controls; power, transformer principles; relay principles; and analyzing control circuits. The Honeywell product number for this impressive 250-page workbook is 71-97083. Check with your local Honeywell distributor or call Honeywell at 1-800-345-6770. ext. 2040. You may also access the Honeywell website at **http://www.honeywell.com/controls.html.**

Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Suggested Activities

Option A

4—Can perform job with no additional training.

3—Moderately skilled—Has performed job during training program; limited additional training may be required.

2—Limited skill—Has performed job during training program; additional training is required to develop skill.

1—Unskilled—Is familiar with process but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job.

Split-Phase Motors
Unit 10

Answers to Written Test

1. a. start
   b. run

2. a. torque
   b. 3/4
   c. dual
   d. (1) small
      (3) belt-drive
      (4) compressors
      (5) hermetic

3. a. phase split
   b. phase split
   c. resistance
   d. start, run
   e. start, torque
   f. lighter
   g. 75%, 80%
   h. single-speed
   i. open-drive

4. a. (2)
   b. (1)
   c. (2)
   d. (2)
   e. (2)

5. a. series
   b. overload
   c. overload, current
   d. NEMA
   e. reversing
   f. start relay coil
   g. lower

6. a. (2)
   b. (1)
   c. (2)
   d. (2)
   e. (1)
   f. (1)
   g. (2)
   h. (1)

Split-Phase Motors
Unit 10

Written Test

Name ________________________________ Date _________ Score _______

1. Complete statements about terms and definitions for split-phase motors. Write in the term that completes each of the following definitions.

   a. The stator winding that is used for starting an electric motor is called a ___________ winding.

   b. The stator winding that is used continuously during normal operations of an electric motor is called a _______________ winding.

2. Complete statements about characteristics and applications of split-phase motors. Write in the information that best completes each of the following statements.

   a. Split-phase motors are small to medium size, relatively low-cost, single-phase motors with low to medium ________________.

   b. Split-phase motors commonly range from 1/20 to __________ Hp.

   c. Split-phase motors come in either 120 VAC or 208/240 VAC, and in ___________ voltage that can be connected to either 120 VAC or 208/240 VAC.

   d. Split-phase motors are used in such applications as:

      (1) ___________ to medium-size direct-drive fans and blowers,

      (2) pumps,

      (3) ______________-______________ blowers,

      (4) refrigerator and freezer ______________________, and

      (5) small, commercial refrigeration ______________________ compressors.

3. Complete statements about split-phase motor construction. Write in the information that best completes each of the following statements.

   a. Like all single-phase motors, split-phase motors must create a ____________ ________________which produces the two-phase current required to start the motor.

Written Test

b. Split-phase motors accomplish the ______________ ______________ by using two stator windings, a start winding and a run winding.

c. Making the start winding longer and out of lighter-gauge wire means it will have more __________________________ than the run winding.

d. When current is applied to both windings at the same time, current through the ______________ winding will lead current running through the ______________ winding.

e. The rotor will be attracted to the ___________ winding pole a little sooner than to the run winding pole, and this attraction provides starting ________________.

f. Because of its _______________ construction, the start winding will burn up if it is left in the circuit longer than a few seconds.

g. A starting mechanism is used to remove the start winding from the circuit when the motor reaches approximately ________ to ________ of its rated speed.

h. Split-phase motors used in ACR applications are usually ___________________-________________motors.

i. Split-phase motors used in ACR applications are either _____________ ________ construction or hermetic construction.

4. Complete statements about split-phase motor starting mechanisms. Circle the number in front of the information that best completes each of the following statements.

   a. The element that differentiates the split-phase motor from other single-phase AC motors is:

      (1) its size.

      (2) the type of starting mechanism required.

   b. Despite their names, starting mechanisms do not "start" motors; their main function is to:

      (1) disconnect starting components.

      (2) keep start and run windings in sync.

Written Test

c. As start mechanisms, open drive motors use centrifugal controls or:

   (1) hard start kits.

   (2) other mechanical means as start mechanisms.

d. Hermetic motors use starting relays because motor starting components must be external; if the devices were internal, arcing points would:

   (1) burn up the run windings.

   (2) ignite refrigeration oil.

e. Some split-phase motors are convertible to capacitor start (CS) motors with the addition of:

   (1) a run capacitor

   (2) a start capacitor.

5. Complete statements about wiring connections for split-phase motors. Write in the information that best completes each of the following statements.

   a. The normally closed centrifugal starting switch on split-phase motors is wired in ______________ with the start winding and opens when the motor reaches approximately 75% to 80% of its rated speed.

   b. There is usually an ____________________ connected in series with one leg of the power.

   c. The _________________ contains a bimetal disc which opens the circuit when it overheats due to high motor temperature or high ____________________ causing the heater wire to heat up.

   d. There are standard ______________ color codes for split-phase motor start and run winding connections.

   e. On motors designed for rotation reversal, the rotation can be changed by _________________ the leads.

   f. Hermetic split-phase motor wiring has the addition of a ______________ ______________ ________________ in the circuit.

   g. Start relay contacts are open initially, close in response to high starting current, and open again in response to _____________normal operating current.

Written Test

6. Complete statements about troubleshooting split-phase motors. Circle the number in front of the information that makes each of the following statements true.

   a. Open drive split-phase motors can usually be disassembled for:

      (1) minor component replacement and rewiring.

      (2) cleaning and some repairs.

   b. Like all motors, open drive split-phase motors will operate cooler and more efficiently when clean; in particular:

      (1) air circulation passages must not be blocked.

      (2) the motor must be in an open, well-ventilated space.

   c. Indications of problems with bearings, thrust washers, or spacers are:

      (1) excessive movement of the stator.

      (2) excessive shaft end play or side play.

   d. The components which most often cause problems in a split-phase motor are the:

      (1) rotors.

      (2) starting components.

   e. The centrifugal control or the switch or relay contacts may stick open or shut, causing the motor not to start or the start windings to:

      (1) remain engaged and burn up.

      (2) perform below par and cause increased amp draw.

   f. Start relay coils may open causing the motor not to start because contacts will not :

      (1) close.

      (2) open.

   g. Mechanical problems can sometimes be repaired, but electrical problems such as open or grounded windings usually require:

      (1) repair at a specialized motor repair shop.

      (2) replacing the motor.

   h. Faulty overloads can sometimes be replaced or for temporary duty, they may be:

      (1) jumpered.

      (2) operated with additional voltage to the motor.

Permission to duplicate this test is granted.

Split-Phase Motors
Unit 10

Unit Evaluation Form

Student Name ______________________ Date _________ Unit Rating _______

Job Sheet 1—Wire a Split-Phase Motor to an AC power source Rating _____

Comments:

Job Sheet 2—Wire a Dual-Voltage, Split-Phase Motor for 120 VAC Rating _____

Comments:

Job Sheet 3—Wire a Dual-Voltage, Split-Phase Motor for 208/240 VAC Rating _____

Comments:

Job Sheet 4—Disassemble, Inspect, Clean, Reassemble, and Check Operation of a Split-Phase Motor Rating _____

Comments:

Other:

Written Test _________ Pretest _________ Posttest _________

Total _________

Teacher Signature Date _________

Student Signature Date _________

Permission to duplicate this form is granted.

Capacitors
Unit 11

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to dedtermine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan enrichment of exceptional students as well as accommodation of special needs students.
4. Add overheads or other graphic materials as desired to enhance instruction.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss and demonstrate the procedures in the job sheets. Review criteria for evaluating these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of written test. Add or modify test items as needed.
13. Give written test.
14. Compile assignment and job sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets added to the unit.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: a SCANS Report for America 2000*. These SCANS skills and competencies have been adapted by MAVCC to help instructors and program planners effectively articulate curriculum.

1. Have samples of both start and run capacitors available for students to examine as the class discusses Objectives 3 and 4. Stress the theory of capacitor use and demonstrate the electrical characteristics of capacitor operation. **Basic skills, science and listening.**
2. As the class discusses Objective 4, take an old capacitor apart so the students can physically see the interior construction of the plates and other elements of the capacitor(s). **Basic skills, science and listening.**
3. Have a typical start capacitor available for demonstration as you present Objective 5. Stress the positioning and operation of the bleed resisistor and the relief port. **Basic skills, science and listening.**
4. Have a typical run capacitor available for demonstration as you present Objective 5. Point out the location of the identified terminal. If you can, find enough run capacitors to demonstrate the arrow, dash, or red dot that is used to indicate the identified terminal. **Basic skills, science and listening.**
5. Prepare students for activities in the asignment sheet by demonstrating how to group capacitors in series and in parallel as presented in Objective 7. **Basic skills, reading and listening.**
6. Assign students to small groups and have members of each group look for applications of capacitors in the ACR lab or a selected installation. Have each group member present findings to the class and discuss why capacitors were required for the applications students found. **Interpersonal skills, team work; basic skills, science and speaking.**

Resources Used in Developing This Unit

1. Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning*. South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.
2. *The Air Conditioning, Heating and Refrigeration News HVAC/R Source Guide*. Troy, MI: Business News Publishing Company, 1995.
3. Wantiez, Gary W. *ACR Electrical Components and Systems*. Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.
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Suggested Activities

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Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Option A

4—Can perform job with no additional training.
3—Moderately skilled—Has performed job during training program; limited additional training may be required.
2—Limited skill—Has performed job during training program; additional training is required to develop skill.
1—Unskilled—Is familiar with process but is unable to perform job.

Option B

Yes—Can perform job with no additional training.
No—Is unable to perform job.

Capacitors
Unit 11

Answers to Assignment Sheets

Assignment Sheet 1

A. (1) 2.5 mfd, 220 VAC
(2) 80 mfd, 600 VAC
(3) 70 mfd, 540 VAC
(4) 5 mfd, 360 VAC
(5) 17.5 mfd, 690 VAC

B. (1) 15 mfd, 110 VAC
(2) 180 mfd, 250 VAC
(3) 280 mfd, 330 VAC
(4) 20 mfd, 120 VAC
(5) 195 mfd, 250 VAC

Capitors
Unit 11

Answers to Written Test

1. a. 6
   b. 3
   c. 1
   d. 4
   e. 2
   f. 5

2. a, b, c, d

3. a. cutting across
   b. change
   c. opposition
   d. inductive reactance
   e. capacitive reactance
   f. impedance
   g. current, voltage

4. a, b, c, d, e, f, g, i, j, k,l

5. a. (2)
   b. (1)
   c. (2)
   d. (2)
   e. (1)

6. a. (2)
   b. (1)

7. a. grouped
   b. two
   c. parallel
   d. greater
   e. series
   f. series
   g. series

Capacitors
Unit 11

Written Test

Name ________________________________ Date _______ Score ______

1. Match each term on the right with its correct definition.

__ a. The factor in an electrical circuit that allows for temporary storage of electrical charges and opposes any change in existing voltage

__ b. A device that uses parallel metal plates or foil separated by a dialectric which allows alternating current to flow and creates capacitance in a circuit; it is also called a condenser

__ c. A substance such as air or mica that is a nonconductor of direct current

__ d. The phenomena whereby AC voltage is induced in a wire when the wire is located within the magnetic field created by current flow

__ e. The combined effect of resistance and reactance or total opposition to the flow of alternating current in an electrical circuit

__ f. The opposition to current flow caused by the combined effect of inductance or capacitance and the frequency of alternating current

1. Dialectric
2. Impedance
3. Capacitor
4. Inductance
5. Reactance
6. Capacitance

2. Select true statements about capacitors in ACR circuit applications. Place an "X" beside each true statement.

__ a. Capacitors are used with several types of single-phase motors to create a phase shift or split which produces the two-phase current required to start single-phase motors.

__ b. The presence of a capacitor in an inductive circuit tends to cancel out the effect of the inductive load on the current/voltage relationship.

__ c. Two inductive coils on separate branches of an AC circuit, one with and one without a capacitor, will each have a different current/voltage relationship.

__ d. When two coils, one with and one without a capacitor, are placed in a motor, they will be out of phase with each other when AC voltage is applied, and this creates starting torque.

Written Test

3. Complete statements about the effects of inductive loads on current/voltage relationships. Write in the information that best completes each of the following statements.

    a. When alternating current flows through wire arranged in a coil, current is induced in the adjacent turns of the coil because the magnetic field of each turn is ____________________ ______________ the wire in the adjacent turns.

    b. The self-induced voltage opposes the current that is causing the magnetic field to build up; therefore, inductance opposes any ________________ in current flow.

    c. The frequency of the alternating current affects the strength of the magnetic field and therefore affects the strength of the ______________________ to current flow.

    d. The combined effect of the two factors, inductance and frequency, is called ________________________ _____________________________.

    e. In a capacitive circuit, the combined effect of capacitance and frequency is called ________________________ _____________________________.

    f. The combined opposition of reactance and resistance is called _______________ which is the total opposition to current flow.

    g. In inductive loads like motors, self-induction causes ___________________ to lag behind _________________________.

4. Select true statements about capacitor construction and operation. Place an "X" beside each true statement.

    __ a. Capacitors contain two metal plates, placed close to one another but not touching.

    __ b. In a capacitive circuit, the two plates are connected to a power source through a switch.

    __ c. At the instant the switch is closed, electrons are attracted from one plate to the positive terminal of the battery, and an equal number of electrons are repelled into the other plate from the negative terminal of the battery.

    __ d. When the switch is opened, one plate is left with a deficiency of electrons and the other plate has an excess of electrons creating a potential difference.

    __ e. If we touch a jumper between the two plates, a temporary electron flow takes place until electrical balance between the plates is restored.

Written Test

__ f. The capacitor is charged when the switch is closed, electrons are stored when the switch is opened, and electrons are discharged when the jumper is added.

__ g. When an AC source is connected in place of the battery, current flows in the circuit.

__ h. Current flows across the gap between the plates to create a type of electrical circuit.

__ i. Capacitors not only allow alternating current flow, but cause the current in a capacitive circuit to lead or stay ahead of the voltage.

__ j. Placing a capacitor in series with an inductive load therefore tends to cancel out the lagging effect of the inductive load on the current and current and voltage will be nearly in phase.

__k. Two coils or windings placed in a motor, one with and one without a capacitor, will be out of phase with each other and create the torque necessary to satrt the motor.

__l. A capacitor may be called a capacitor or a condenser and may be indicated by the symbol -)| or -||- .

5. Complete statements about types of capacitors. Circle the number in front of the information that best completes each of the following statements.

   a. If you were differentiating between start capacitors and run capacitors, you should say that:

      (1) start capacitors are rated for specific motors and run capacitors can be used with any motor.

      (2) start capacitors are used only while a motor is starting and run capacitors are used continuously while the motor is running.

   b. If you were talking distinguishing packaging features of start and run capacitors, you should say that:

      (1) start capacitors are in a round bakelite case and run capacitors are in an oval-shaped or round metal case.

      (2) start capacitors may be round or even square, but run capacitors are always oval shaped.

Written Test

c. If you were talking about safety features on a start capacitor, you would have to state that:

   (1) the bakelite case resists the intense heat the capacitor is subjected to.

   (2) the bleed resistor permits discharge after the capacitor is disconnected from power and the relief port permits safe release of pressure in the event of capacitor failure.

d. Since run capacitors generate a lot of heat because of continuous operation, they are:

   (1) enclosed in metal cases that will expand instead of cracking.

   (2) filled with oil or some other substance that dissipates heat.

e. The identified terminal on a run capacitor is:

   (1) marked with a red dot, a dash, or an arrow.

   (2) always marked with an arrow plus either a red dot or a dash.

6. Apply guidelines for capacitor replacement. Circle the number in front of the statement that best demonstrates proper capacitor replacement.

   a. The one general rule that applies to all capacitor replacement is:

      (1) never replace a capacitor with a lower mfd rating than the original capacitor.

      (2) never install a capacitor with a voltage rating lower than the one being replaced.

   b. Replacement start capacitors and run capacitors do not have to have the same mfd ratings as the capacitors they replace, but:

      (1) a run capacitor should be within ±10% of the original mfd, and a start capacitor should be no more than 10% to 20% higher than the original mfd.

      (2) a start capacitor should be within 5% of the original mfd, and a run capacitor should be no more than 25% to 30% higher than the original mfd.

Written Test

7. Complete statements about grouping capacitors. Write in the information that best completes each of the following statements.

   a. When a technician does not have the proper replacement capacitor, capacitors can be ________________ or connected together to produce a proper voltage or mfd rating.

   b. Capacitor manufacturers do not recommend grouping more than _________ capacitors.

   c. The mfd rating of capacitors connected in _________________ is equal to the sum of the mfd rating of the individual capacitors.

   d. The voltage rating of each capacitor connected in parallel must be equal to or ___________________ than the voltage rating of the capacitor being replaced.

   e. The mfd rating of capacitors connected in ____________ can be calculated using the following formula:

   $$C_T = \frac{C1 \times C2}{C1 + C2}$$

   f. The sum of the voltage ratings of capacitors connected in __________ must be equal to or greater than the voltage rating of the capacitor being replaced.

   g. Each of the capacitors connected in ___________ should have the same mfd rating.

Permission to duplicate this test is granted.

Capacitors
Unit 11

Unit Evaluation Form

Student Name ____________________ Date __________ Unit Rating __________

Assignment Sheet 1—Calculate Ratings of Grouped Capacitors Rating _____

Comments:

Job Sheet 1—Check Capacitors With an Analog Ohmmeter Rating _____

Comments:

Job Sheet 2—Check Capacitors With a Capacitor Analyzer Rating _____

Comments:

Other:

Written Test __________ Pretest __________ Posttest __________

Total __________

Teacher Signature Date __________

Student Signature Date __________

Permission to duplicate this form is granted.

Capacitor Motors
Unit 12

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan enrichment of exceptional students as well as accommodation of special needs students.
4. Add overheads or other graphic materials as desired to enhance instruction.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss and demonstrate the procedures in the job sheets. Review criteria for evaluating these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of written test. Add or modify test items as needed.
13. Give written test.
14. Compile assignment and job sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets added to the unit.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: a SCANS Report for America 2000.* These SCANS skills and competencies have been adapted by MAVCC to help instructors and program planners effectively articulate curriculum.

1. Have different capacitor motors on hand as students discuss Objectives 2 and 3. Stress the special applications of capacitor motors. **Basic skills, science and listening.**
2. As the class discusses Objective 4, have a CS motor available for demonstration. **Basic skills, science and listening.**
3. As the class discusses Objective 5, have a PSC motor available for demonstration. **Basic skills, science and listening.**
4. As students discuss Objective 6, have a CSR motor available for demonstration. **Basic skills, science and listening.**
5. Prepare students for activities in the assignment sheets by demonstrating wiring procedures for the different kinds of capacitor motors. **Basic skills, reading and listening.**
6. Assign students to small groups and have members of each group look for applications of capacitor motors at home or in a business where they have access. Have each group member present findings to the class and discuss why capacitor motors are popular for certain applications. **Interpersonal skills, team work; basic skills, science and speaking.**

Resources Used in Developing This Unit

1. Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.
2. *The Air Conditioning, Heating and Refrigeration News HVAC/R Source Guide.* Troy, MI: Business News Publishing Company, 1995.
3. Wantiez, Gary W. *ACR Electrical Components and Systems.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.
4. Smreker, Eugene and King Calvert. *Major Appliance Repair.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1987.

Suggested Supplemental Resources

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Syracuse, NY 13221

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Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Option A

4—Can perform job with no additional training.
3—Moderately skilled—Has performed job during training program; limited additional training may be required.
2—Limited skill—Has performed job during training program; additional training is required to develop skill.
1—Unskilled—Is familiar with process but is unable to perform job.

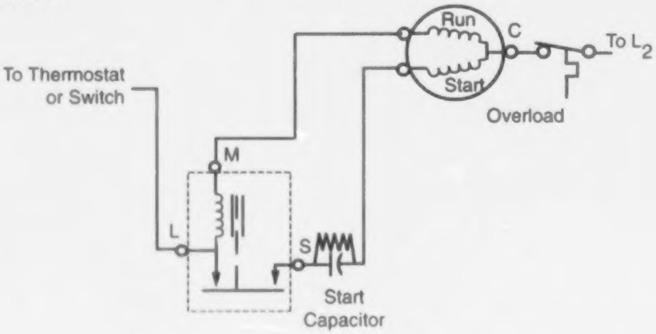
Option B

Yes—Can perform job with no additional training.
No—Is unable to perform job.

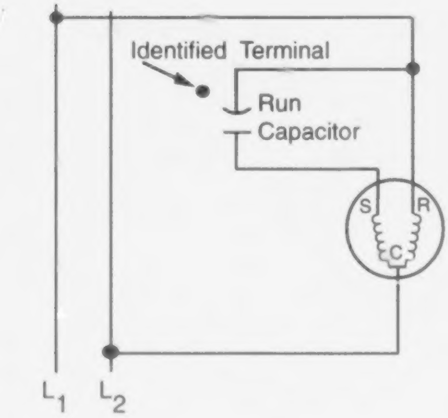
Capacitor Motors
Unit 12

Answers to Assignment Sheets

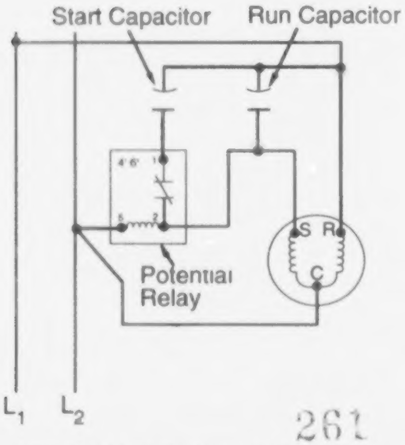
Assignment Sheet 1


Run
C
To L2
To Thermostat or Switch
Start
Overload
M
L
S
Start Capacitor

Assignment Sheet 2


Identified Terminal
Run Capacitor
S
R
C
L1
L2

Assignment Sheet 3


Start Capacitor
Run Capacitor
1
2
5
S
R
C
Potential Relay
L1
L2

Capacitor Motors
Unit 12

Answers to Written Test

1. a. 3
   b. 2
   c. 4
   d. 1
   e. 5

2. a, c, d

3. a. start, run
   b. when, what
   c. start, run
   d. disconnected
   e. capacitor
   f. start
   g. amps
   h. more, less
   i. amps

4. a. (2)
   b. (1)
   c. (1)

5. a. excellent
   b. wide range
   c. can often
   d. not disconnected
   e. increased
   f. (1) medium
      (2) hermetic
      (3) commercial
      (4) small

6. a. (1)
   b. (2)
   c. (2)
   d. (2)

Answers to Written Test

7. a. open-drive
   b. centrifugal
   c. capacitors, starting, motor
   d. capacitors, start
   e. indications
   f. usually

8. a. wrong
   b. rated
   c. EMF
   d. switches, contacts
   e. open
   f. stuck closed, stuck closed
   g. analyzer

Capacitor Motors
Unit 12

Written Test

Name ____ Date ________ Score ________

1. Match each term on the right with its correct definition:

__ a. Motors which use a start capacitor and/or a run capacitor

__ b. Motors which use both start and run capacitors

__ c. Motors which use only start capacitors

__ d. A packaged item containing a potential relay and a start capacitor designed to be added to a PSC motor to convert it to a CSR motor

__ e. Motors which use only run capacitors

1. Hard start kit
2. Capacitor Start-Capacitor Run Motors (CSR)
3. Capacitor motors
4. Capacitor Start-Induction Run Motors (CSIR or CS)
5. Permanent Split Capacitor Motors (PSC)

2. Select true statements about how capacitors affect motors. Place an "X" beside each true statement.

__ a. Although the primary reason for using capacitors with motors is to achieve starting torque, capacitors have other effects on motors.

__ b. Using a capacitor too large can cause slow starting and excessive start amps.

__ c. Since capacitance reduces running current, using a capacitor continuously can increase motor efficiency.

__ d. Using a capacitor either too large or too small can cause a motor to overheat.

Written Test

3. Complete statements about applications of capacitors to motors. Write in the information that best completes each of the following statements.

   a. All capacitor motors are essentially variations of the basic split-phase motor with a ____________ winding and a ____________ winding.

   b. All capacitors are connected in series with the start winding, so capacitor names run and start refer to "____________" the capacitors are used and not "____________" they are connected to.

   c. ____________ capacitors are used by motors only until the motor gets started, and ____________ capacitors are used all the time motors are running.

   d. In split-phase motors, the start winding is ____________________________ as the motor gets up to speed.

   e. In CS motors, the start winding is disconnected just like in a split-phase motor, but a start ______________________ is added to the start winding circuit for added torque.

   f. Some split-phase motors, small refrigeration compressor motors in particular, are designed to be convertible to CS motors by adding a ______________ capacitor.

   g. In PSC motors, the start winding is not disconnected, but remains connected through a run capacitor to reduce running ______________ during operation.

   h. Using the run capacitor in a PSC motor starting circuit gives the motor ___________ torque than a split-phase motor with no capacitor, but ___________ torque than a CS motor with a start capacitor.

   i. The CSR motor combines the features of a CS motor and a PSC motor by using a start capacitor connected temporarily to the start winding for initial torque, and a run capacitor connected continuously to the start winding during operation to reduce running ___________ .

4. Select true statements about CS motor characteristics and applications. Circle the number in front of the information that makes each of the following statements true.

   a. CS motors are medium to large size, medium cost motors with medium to high torque and average running efficiency, and are used in such applications as:

      (1) medium size direct drive fans and blowers.

      (2) belt drive blowers and belt drive compressors.

Written Test

b. CS motors come in several single voltages and dual voltage, but:

   (1) CS motors are usually single speed and rotation usually cannot be reversed.

   (2) CS motors are frequently dual voltage with rotation that can be electrically reversed.

c. After a CS motor starts:

   (1) switching must be used to remove the start capacitor and start winding from the circuit.

   (2) the start winding combines with the run winding to add to motor running efficiency.

5. Complete statements about PSC motor characteristics and applications. Write in the information that best completes each of the following statements.

   a. PSC motors are medium to large size, medium cost motors with medium torque and ____________________ running efficiency.

   b. PSC motors come in a ______________ _____________ of single voltages, but not in dual voltage.

   c. PSC motors come in single or multiple speeds and direction of rotation ______ _______________ be reversed.

   d. No internal or external switching must be provided on a PSC motor because the start winding is __________ ______________________________.

   e. Some PSC motors are designed so that a potential relay and start capacitor may be added to convert a PSC motor to a CSR motor for ___________________ starting torque.

   f. PSC motors are used in such applications as:

      (1) ______________ size, direct drive fans and blowers,

      (2) residential/light commercial air conditioning _______________________ compressors,

      (3) ________________________ refrigeration hermetic compressors,

      (4) _____________, semi-hermetic compressors,

Written Test

6. Select true statements about CSR motor characteristics and applications. Circle the number in front of the information that makes each of the following statements true.

   a. CSR motors are medium to large size, high-cost motors with high torque and:

      (1) excellent running efficiency.

      (2) average running efficiency.

   b. CSR motors are usually single speed and:

      (1) rotation usually can be reversed.

      (2) rotation usually cannot be reversed.

   c. CSR motors require the external switching of a potential relay to remove the start capacitor from the start winding circuit after a CSR motor starts; but like a PSC motor, the run capacitor is left in the circuit to improve:

      (1) torque.

      (2) running efficiency.

   d. CSR motors are used primarily in compressors of all types, especially:

      (1) open-drive compressors.

      (2) hermetic compressors.

7. Complete statements about troubleshooting capacitor motors. Write in the information that best completes each of the following statements.

   a. The mechanical components of open drive capacitor motors are serviced in the same way as all ____________ ____________ motors.

   b. Open-drive CS motors use the same type of ______________________ controls as split-phase motors, and troubleshooting these controls is the same as for split-phase motors.

   c. The key to troubleshooting most capacitor motor problems is determining if the problem is with the ____________________, other ____________________ components, or the ____________________.

   d. If a capacitor motor has voltage available but will not start or run properly, it will usually save time to check ______________________ and ______________ components before checking the motor.

   e. The condition of capacitors and start components can also give good ______________________ of what happened to failed motors.

   f. External motor starting components such as capacitors and start relays should ____________________ be replaced anytime a capacitor motor is replaced.

Written Test

8. Complete statements about troubleshooting capacitor motor start components. Write in the information that best completes each of the following statements.

   a. Because technicians often find that someone else has installed the ______________ start component or wired the component improperly, always check for these problems before continuing any other troubleshooting.

   b. Make sure the motor is operating under conditions for which it is ______________, conditions such as ambient temperature, line voltage, duty cycle, and motor load.

   c. Check such motor conditions as bearings, run amps, and back ____________.

   d. Check starting ____________________ or start relay ____________________ to make sure they are closed during starting and open when the motor is running.

   e. Check start relays carefully for proper operation; if the coil is ______________ or if there is any possibility the relay is not working properly, replace it.

   f. Anytime a capacitor fails, check carefully for starting switches ____________ ______________ or relays with contacts _______________ ______________ because either condition always causes capacitor failure.

   g. When a capacitor does not check open, shorted, or grounded, but the motor still has trouble starting, replace the capacitor or use an ____________________ to check capacitor capacitance and compare it to capacitor rating.

Permission to duplicate this test is granted.

Capacitor Motors
Unit 12

Unit Evaluation Form

Name ______________________ Date __________ Overall Rating _____

Assignment Sheet 1—Draw Connecting Wiring for a CS Motor With a Current Relay — Rating_____

Comments:

Assignment Sheet 2—Draw Connecting Wiring for a PSC Motor — Rating_____

Comments:

Assignment Sheet 3—Draw Connecting Wiring For a CSR Motor — Rating_____

Comments:

Job Sheet 1—Wire a CS Compressor With a Current Relay — Rating_____

Comments:

Job Sheet 2—Wire a PSC Motor — Rating_____

Comments:

Job Sheet 3—Wire a CSR Compressor Motor — Rating_____

Comments:

Job Sheet 4—Disassemble, Inspect, Clean, Reassemble, and Check Operation of a PSC fan motor — Rating_____

Comments:

Job Sheet 5—Use a Hermetic Analyzer to Start, Reverse, and Check Operation of a PSC Compressor Motor — Rating_____

Comments:

Job Sheet 6—Install a Hard Start Kit — Rating_____

Comments:

Unit Evaluation Form

Other:

Written Test: __________ Pretest __________ Posttest __________

Total __________

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

Permission to duplicate this form is granted.

Three-Phase Motors
Unit 13

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan enrichment of exceptional students as well as accommodation of special needs students.

4. Add overheads or other graphic materials as desired to enhance instruction.

5. Develop teaching plan. Adjust for different learning styles.

6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.

8. Discuss unit and specific objectives.

9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.

10. Discuss and demonstrate the procedures in the job sheet. Review criteria for evaluating these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

12. Make copies of written test. Add or modify test items as needed.

13. Give written test.

14. Compile assignment and job sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets added to the unit.

15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: A SCANS Report for America 2000.* These SCANS skills and competencies have been adapted by MAVCC to help instructors and program planners effectively articulate curriculum.

1. Have a three-phase motor on hand as students begin discussing Objective 2. Help establish for students why these motors are different from shaded-pole and split-phase motors and what applications they are especially suitable for. **Basic skills, science and listening.**
2. Disassemble a three-phase motor to demonstrate the motor construction elements presented in Objective 3. Impress upon students the important concepts behind a design that eliminates start and run windings. **Basic skills, science and listening.**
3. Prepare students for activities in the assignment sheets by demonstrating wiring connections as presented in Objective 4, and demonstrate the proper use of the Motor Connections Chart presented in Assignment Sheet 1. **Basic skills, reading and listening.**
4. Assign students to small groups and have members of each group look for applications of three-phase motors in a selected residence or industry. Have each group member present findings to the class and discuss why three-phase motors were probably selected for the applications. Students may want to add observations about cost and efficiency to complete their reports. **Interpersonal skills, team work; basic skills, science and speaking.**

Resources Used in Developing This Unit

1. Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.
2. *The Air Conditioning, Heating and Refrigeration News HVAC/R Source Guide.* Troy, MI: Business News Publishing Company, 1995.
3. Wantiez, Gary W. *ACR Electrical Components and Systems.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.
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Suggested Activities

Suggested Supplemental Resources

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Suggested Activities

Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Option A

4—Can perform job with no additional training.
3—Moderately skilled—Has performed job during training program; limited additional training may be required.
2—Limited skill—Has performed job during training program; additional training is required to develop skill.
1—Unskilled—Is familiar with process but is unable to perform job.

Option B

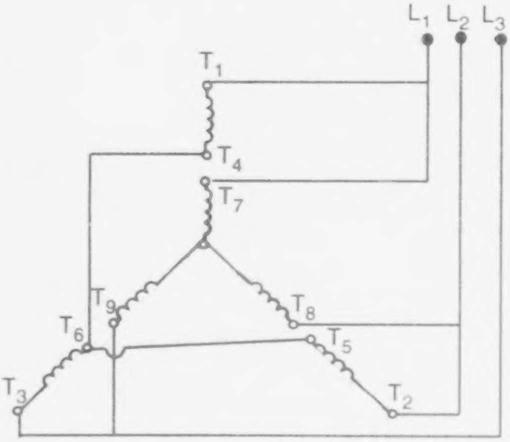
Yes—Can perform job with no additional training.
No—Is unable to perform job.

Three-Phase Motors
Unit 13

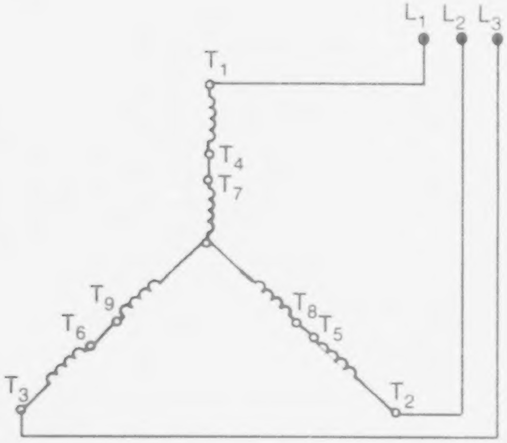
Answers to Assignment Sheet

Assignment Sheet 1

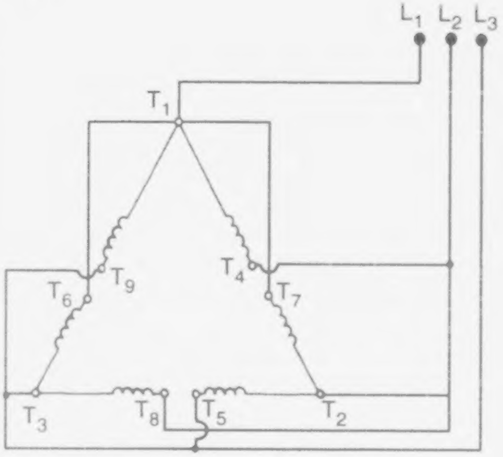
A.


L_1
L_2
L_3
T_1
T_4
T_7
T_9
T_8
T_6
T_5
T_3
T_2

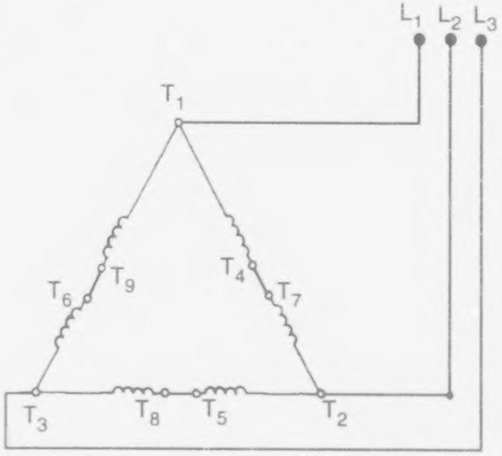
B.


L_1
L_2
L_3
T_1
T_4
T_7
T_9
T_8
T_6
T_5
T_3
T_2

C.


L_1
L_2
L_3
T_1
T_4
T_9
T_6
T_7
T_3
T_8
T_5
T_2

D.


L_1
L_2
L_3
T_1
T_4
T_9
T_7
T_6
T_3
T_8
T_5
T_2

Three-Phase Motors
Unit 13

Answers to Written Test

1. a. 3
   b. 5
   c. 2
   d. 1
   e. 4

2. a. smaller, fewer
   b. several
   c. reliable
   d. (1) large
      (2) medium
      (3) semihermetic
   e. package

3. a, c, d, f, g

4. a. (2)
   b. (2)
   c. (1)

5. a. (2)
   b. (1)
   c. (2)
   d. (1)
   e. (2)
   f. (2)

Three-Phase Motors
Unit 13

Written Test

Name ______________________________________ **Date** ________ **Score** ______

1. Match each term on the right with its correct definition.

   __ a. Shaped like a triangle

   __ b. Shaped like the exercise wheel used by pet rodents

   __ c. The tendency of AC motors to adjust themselves to a constant speed depending on the AC frequency and the number of poles in the motor

   __ d. A motor that uses three-phase power which consists of three hot legs

   __ e. Shaped like the letter Y

   1. Three-phase motor
   2. Synchronous speed
   3. Delta
   4. Wye
   5. Squirrel cage

2. Complete statements about characteristics and applications of three-phase motors. Write in the information that best completes each of the following statements.

   a. Three-phase motors are larger Hp and more expensive than single-phase motors, but achieve torque with ___________ wire and ___________ components.

   b. Three-phase motors come in _____________ voltages and single or dual-voltage.

   c. Simpler construction and fewer components make three-phase motors more _______________ than single-phase motors.

   d. Three-phase motors are used in such applications as:

      (1) _____________ blowers and fans,

      (2) _____________ and large hermetic compressor motors,

      (3) _________________________ compressor motors,

   e. Single-phase and three-phase motors are sometimes used in the same piece of equipment such as a __________________________ heating/cooling unit with single-phase fan and blower motors and a three-phase compressor motor.

Written Test

3. Select true statements about three-phase motor construction. Place an "X" beside each true statement.

__ a. Since three-phase motors use a three-phase power supply, they do not need to create the phase shift or split that single-phase motors require to achieve starting torque.

__ b. Three-phase motors have a stator with three windings, each with a different resistance.

__ c. Each winding is 120 electrical degrees out of phase with the adjacent winding which means that the attraction of the stator is continuously 120° ahead of the rotor.

__ d. The continuous attraction/repulsion gives a three-phase motor both starting torque and continuous running torque.

__ e. Stator windings are either delta wound or shaded-pole.

__ f. Three-phase motors must have either internal or external overload protection that disconnects at least two windings to prevent single-phasing which could cause the motor to burn up.

__ g. Three-phase motors are either synchronous or squirrel-cage.

__ h. Synchronous three-phase motors usually use an external AC source to excite the rotor for extra starting torque.

__ i. Squirrel-cage three-phase motors use a standard rotor.

4. Complete statements about wiring connections for three-phase motors. Circle the number in front of the information that best completes each of the following statements.

a. Single voltage three-phase motors have three leads which connect to:

(1) any two-leg legs plus the neutral of a two-leg power source.

(2) the three legs of three-phase power.

b. Dual voltage three-phase motors may have:

(1) three but usually have six motor leads.

(2) six but usually have nine motor leads.

c. The rotation of any three-phase motor may be reversed by:

(1) switching any two of the line voltage leads.

(2) moving all three leads to new connections.

Written Test

5. Select true statements about troubleshooting three-phase motors. Circle the number in front of the information that makes each of the following statements true.

   a. Three-phase motors are subject to problems that other types of motors are subject to, but the most common problem with three-phase motors is:

      (1) overheating because of power fluctuations.

      (2) lack of proper three-phase power to the motor.

   b. When checking power for a three-phase motor it is important to:

      (1) check power to the disconnect and to the motor.

      (2) check power to the disconnect while it is closed.

   c. To avoid misleading readings when checking a disconnect:

      (1) check power across the disconnect.

      (2) check power all three ways, and with the disconnect open.

   d. For checking fuses:

      (1) remove the fuses and check them with an ohmmeter.

      (2) use a standard voltmeter check.

   e. An open internal overload in a three-phase motor can cause an indication that two or more windings are open, but before condemning the motor:

      (1) check starting components that may be causing the overload to trip.

      (2) allow plenty of time for the overload to reset.

   f. The three-phase motors that can be repaired at a motor repair facility are:

      (1) hermetic motors.

      (2) Open-drive motors.

Permission to duplicate this test is granted.

Three-Phase Motors
Unit 13

Unit Evaluation Form

Student Name ____________________________ Date __________ Unit Rating _____

Assignment Sheet 1—Draw Connecting Wiring for Wye Wound and Delta Wound Dual-Voltage Motors Rating _____

Comments:

Job Sheet 1—Wire a Dual-Voltage, Three-Phase Motor, Reverse Rotation, and Check Operation Rating _____

Comments:

Other:

Written Test __________ Pretest __________ Posttest __________

Total __________

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

Permission to duplicate this form is granted.

Troubleshooting ACR System Electrical Circuits
Unit 14

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan enrichment of exceptional students as well as accommodation of special needs students.
4. Add overheads or other graphic materials as desired to enhance instruction.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss and demonstrate the procedures in the assignment and job sheets. Review criteria for evaluating these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of written test. Add or modify test items as needed.
13. Give written test.
14. Compile assignment and job sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignment or job sheets added to the unit.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified in *What Work Requires of Schools: a SCANS Report for America 2000*. These SCANS skills and competencies have been adapted by MAVCC to help instructors and program planners effectively articulate curriculum.

1. Review "Unit 1, Fundamentals of Electricity." Have students refresh their knowledge of basic series, parallel, and series-parallel circuits. Talk about the application of basic circuits in ACR system electrical circuits. **Basic skills, science and listening.**

2. Stress the importance of the elements in Objective 3 to the overall objective of troubleshooting. Impress upon students the importance of keeping notes so they can reference them to help with similar troubleshooting problems they confront later in their service careers. **Basic skills, science and listening.**

3. Demonstrate the hopscotching method presented in Objective 6. Have a circuit with faults inserted so students can practice with you in hopscotching to isolate problems. **Basic skills, science and listening.**

4. Prepare motors or other components to demonstrate shorts and grounds as presented in Objective 9. **Basic skills, science and listening.**

5. Have students prepare short reports of an electrical problem they have solved at home or someplace other than the classroom, even an automobile. Have students present their reports to the class. **Basic skills, writing and speaking.**

Resources Used in Developing This Unit

1. Althouse, Andrew D. et al. *Modern Refrigeration and Air Conditioning.* South Holland, IL: The Goodheart-Willcox Company, Inc., 1995.

2. *The Air Conditioning, Heating and Refrigeration News HVAC/R Source Guide.* Troy, MI: Business News Publishing Company, 1995.

3. Wantiez, Gary W. *ACR Electrical Components and Systems.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1984.

4. Smreker, Eugene and King Calvert. *Major Appliance Repair.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1987.

Suggested Activities

Suggested Supplemental Resources

Two websites of special interest to ACR students and instructors are: **http://www.hvaconline.com** and **http://www.environ.com/hvacmall.htm**. With certain membership requirements, both of these sites permit you to input questions about ACR service and receive answers from professionals in every area from installation to all kinds of troubleshooting. These sites can also be used to access news from professional HVAC organizations, some of which are listed here:

Air Conditioning and Refrigeration Institute—**http://www.ari.org**
Air Conditioning Contractors of America—**http://www.acca.org**
American Society of Heating, Refrigerating, and Air Conditioning Engineers—**http://www.ashrae.org**

"Analyzing Control Circuits" and "Inductive and Capacitive Circuits" are two topics presented in Honeywell's *Fundamentals of Residential Controls.* The inexpensive text ($9.00) is one of Honeywell's programmed instruction books built around a step-by-step, question-answer format. Other topics include: nature of electricity; rules governing electricity; power; transformer principles; relay principles; and principles of motor operation. The Honeywell product number for this impressive 250-page workbook is 71-97083. Check with your local Honeywell distributor or call Honeywell at 1-800-345-6770. ext. 2040. You may also access the Honeywell website at **http://www.honeywell.com/controls.html.**

Suggested Activities

Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Option A

4—Can perform job with no additional training.
3—Moderately skilled—Has performed job during training program; limited additional training may be required.
2—Limited skill—Has performed job during training program; additional training is required to develop skill.
1—Unskilled—Is familiar with process but is unable to perform job.

Option B

Yes—Can perform job with no additional training.
No—Is unable to perform job.

Troubleshooting ACR System Electrical Circuits
Unit 14

Answers to Assignment Sheets

Assignment Sheet 1

A. II5V, 24V, 230V

B. Light
Indoor blower motor low-speed winding
Indoor blower motor high-speed winding
Transformer primary
Cooling contactor coil
Cooling anticipator
Adjustable heating anticipator
Gas valve
Blower relay coil
Compressor motor run winding
Compressor motor start winding
Start relay coil
Outdoor fan motor run winding
Outdoor fan motor start winding
Crankcase heater

C. Thermostat temperature switch
Heat off cool switch
High pressure switch
Low pressure switch

D.

D.	Indoor blower motor	4
	Compressor motor	3
	Outdoor fan motor	2

E. Hot leg

F. Gas valve and adjustable heating anticipator

G. Compressor motor start winding

Assignment Sheet 2

A. No. This would indicate that 115V is not available to the IBM circuit.

B. None.

C. If the thermostat fan switch is in the AUTO position, the indoor blower motor will stop.

D. The compressor motor start capacitor

Answers to Assignment Sheets

E. Blower relay normally closed contacts
Blower interlock switch
Fan switch

F. Thermostat temperature switch
Adjustable heat anticipator
Heat off cool switch
Limit switch
Rollout switch

G. Thermostat automatic on switch
Thermostat temperature switch
Heat off cool switch

Assignment Sheet 3

A. Use a voltmeter with probes at L_1 and L_2.

B. (1) With the hopscotch method, use voltmeter with probes where BR connects to the hot leg and where IBM connects to the neutral leg, and then at H and C on IBM.

(2) With other than the hopscotch method, use an ohmmeter with probes at each side of contacts, and with power off and at least one side of contacts disconnected.

C. Use an ohmmeter with all motor wires disconnected.

D. Clamp an ammeter around either wire between L_1 or L_2 and the CH.

E. Clamp an ammeter around the wire to C on the compressor and then momentarily push CC contacts closed, or with ammeter attached, turn off the power, jumper the HP and momentarily turn power back on.

Assignment Sheet 4

A. The thermostat temperature switch or the heat off cool switch
Replace the thermostat.

B. The compressor motor or compressor motor start components

C. The limit switch or the rollout switch

D. The transformer

E. Jumper the limit switch temporarily.

F. Jumper the high-pressure switch.

Troubleshooting ACR System Electrical Circuits
Unit 14

Answers to Written Test

1. a. 3
   b. 9
   c. 10
   d. 5
   e. 2
   f. 7
   g. 6
   h. 1
   i. 4
   j. 8

2. a. operation
   b. experience
   c. opens, shorts, grounds (order may vary)
   d. jumpered
   e. cost

3. a. (2)
   b. (2)
   c. (4)
   d. (2)

4. a. experience
   b. voltmeter
   c. voltmeter
   d. ammeter
   e. ammeter, ammeter
   f. ohmmeter
   g. (1) disconnected
      (2) discharged
      (3) isolated
   h. on, off

5. b, d, f, g

6. a. (2)
   b. (2)
   c. (2)
   d. (2)

7. a, b, d, f, g

Answers to Written Test

8. a. continuity
   b. disconnect
   c. isolated
   d. remove
   e. zero
   f. infinity, zero, zero
   g. infinite, resistance
   h. battery current

9. a. similar
   b. alternative, shortcut
   c. direct
   d. impeded
   e. lower
   f. continue
   g. green

10. a. (2)
    b. (2)
    c. (2)
    d. (2)

11. a. (1)
    b. (1)
    c. (2)
    d. (2)

Troubleshooting ACR System Electrical Circuits
Unit 14

Written Test

Name____Date________Score ______

1. Match each term on the right with its correct definition.

__ a. A complete electrical path

__ b. Any device that operates or regulates electrical or mechanical systems

__ c. An undesired path to the earth ground

__ d. A control which responds to such conditions as temperature or pressure and opens or closes circuits when maximum or minimum conditions are reached; usually used for safety purposes

__ e. Any device that uses or consumes electricity by converting it into heat, light, or mechanical motion

__ f. Lack of continuity in an electrical circuit

__ g. A control such as a thermostat which responds to a change in conditions and initiates action

__ h. A control such as a fan relay which responds to a signal from an operating control and stops and starts equipment such as motors or valves

__ i. A direct path to an earth ground to prevent damage to equipment or injury to people

__ j. An improper path in an electrical circuit

1. Primary control
2. Load
3. Continuity
4. Safety ground
5. Limit control
6. Operating control
7. Open
8. Short
9. Control
10. Ground

2. Complete statements about guidelines for troubleshooting ACR system electrical circuits. Write in the information that best completes each of the following statements.

a. Identify circuit components and their ______________________ using electrical diagrams and information about the specific equipment.

b. Select the appropriate test meter based on the status of the equipment and your own ________________________.

c. Use test instruments and your senses and experience to establish where power is available, what is and what is not operating, how loads are operating, and where faults such as ____________________, ______________________, and ___________________ are located.

d. Open switches, safety devices, or loads in series may have to be temporarily ________________________ in order to identify the condition of the entire circuit or system.

Written Test

e. Recommend corrective action only after you have determined the relative _______________ or any additional problems.

3. Select true statements about identifying circuit components and their operations. Circle the number in front of the information that makes each of the following statements true.

   a. In an operating ACR circuit, an operating control senses a need for a change in conditions and signals a primary control which starts or stops the equipment which will make the change, but only if:

      (1) the change will affect just one circuit.

      (2) the limit control senses that it is safe to do so.

   b. In order to troubleshoot ACR electrical systems, a technician must identify which components are loads, what is controlling each load, and:

      (1) how the loads are affected by limit switches.

      (2) what type of controls they are.

   c. In the following pictorial the electrical components can be identified as:

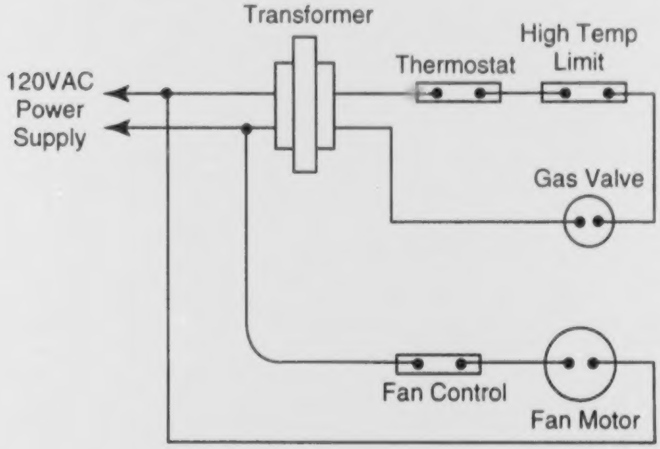
      (1) sources: 120VAC power supply and the 24VAC secondary of the transformer,

      (2) loads: fan motor, gas valve, and primary of the transformer, and

      (3) controls: fan motor controlled by fan control, gas valve controlled by thermostat and limit control, and the transformer primary has no control.

      (4) all of the above.

      (5) none of the above.



290

d. Motors with more than one winding such as two-speed motors and split-phase motors are actually:

   (1) one load on a dual-voltage circuit.

   (2) two loads in one device.

4. Complete statements about guidelines for test meter selection. Write in the information that best completes each of the following statements.

   a. Which test meter to use in a given situation depends on the status of the equipment and the technician's ________________________.

   b. Use a ______________________ to determine if source voltage is available to the equipment or to a specific component.

   c. When the system is fully or partially operating, use a ____________________ to determine at what point the circuit is broken.

   d. Use an ____________________ to determine whether a load such as a motor or electric heat strip is operating properly, that is, drawing the correct amount of current.

   e. An analog ____________________ or a digital __________________ capable of reading momentary amp draw is essential in checking motor starting amps and starting components.

   f. Use an ____________________ to check for continuity of a circuit or component.

   g. Use an ohmmeter only with:

      (1) the power turned off or __________________________,

      (2) capacitors _____________________, and

      (3) the circuit or component _________________________.

   h. To use voltmeters and ammeters, power must be _____, but to use an ohmmeter, power must be _______.

5. Select true statements about using a voltmeter. Place an "X" beside each true statement.

   __ a. The first step in almost any troubleshooting situation is to disconnect all power.

   __ b. If any line voltage components are operating, it requires no meter to come to the conclusion that power is available.

   __ c. If no components are operating, use a voltmeter to check for voltage at the point where the source of supply enters the building or residence.

   __ d. If voltage is present, the problem is in the equipment; if voltage is not present, the problem is in the source.

__ e. If the problem is in the source, use the ohmmeter to check at points such as fuses or breakers to determine where power stops.

__ f. Blown fuses or breakers are indications that some load is probably drawing too much current.

__ g. If voltage is available to the equipment, use a voltmeter to check if voltage is available to individual loads.

__ h. Once you have established that voltage is available to the equipment but not to the load, the simplest method to determine which component in a circuit is open is to remove and check individual components with an ohmmeter.

6. Solve problems about applying the hopscotch method for troubleshooting. Circle the number in front of the information that best solves each of the following problems.

a. You have established that voltage is available to the equipment you are troubleshooting and decide to begin the hopscotch method of troubleshooting to isolate the problem.

(1) You need to decide which load is most suspect of not operating.

(2) You need to establish if power is available to the load.

b. You have just completed the first step in using the hopscotch method of troubleshooting and have decided that the first switch is open. You continue with hopscotching and move on to the second switch.

(1) You are using the method properly, but you need to make notes about the first switch because you may need to replace it.

(2) You have isolated the problem, so check the equipment for the cause of the problem before you waste any more time hopscotching.

c. You are talking with a coworker about what causes most circuit opens and the coworker says that shorts cause the most circuit opens.

(1) You need to remember that grounds cause most circuit opens.

(2) You need to remember that open switches cause most circuit opens.

d. You have found an open and corrected it and you start to operate the equipment.

(1) The problem is you need to verify that connections on either side of the open you corrected are properly secured.

(2) The problem is that you need to do your best to determine what caused the open before you operate the equipment.

Written Test

7. Select true statements about using an ammeter. Place an "X" beside each true statement.

   __ a. Use an ammeter to test the amount of current a load is drawing, and compare the amp draw to the OEM specifications.

   __ b. Name plate rating for F.L.A. represents amp draw under full load conditions, so be sure to evaluate the operating conditions of the load.

   __ c. Ammeter checks of a CSR motor tell a technician the condition of the motor, but an ammeter cannot be used to evaluate starting components or motor operation.

   __ d. Use an ammeter to determine if loads you cannot see are or are not operating.

   __ e. When the meter you are using does not have a scale small enough to read the very low current draw of some loads, switch to a different wire.

   __ f. To prevent damage to an ammeter, remember that motors have relatively high starting amps, so be sure to set an ammeter high enough to handle three to four times F.L.A. and then change to a lower scale after the motor starts.

   __ g. Because of the short duration of start amps, most digital ammeters will not read start amps.

8. Complete statements about using an ohmmeter. Write in the information that best completes each of the following statements.

   a. Use an ohmmeter to check ______________________ or to find opens, shorts, and grounds.

   b. Before using an ohmmeter, ____________________ the power and at least one end of the component you are checking.

   c. Use an ohmmeter for checking circuits only if the circuit has been ________________ from other circuits and components.

   d. To avoid misleading readings and misinterpreting ohmmeter readings, _____________ a component before checking it with an ohmmeter.

   e. ______________ an ohmmeter before using it and each time you change scales because it is the only way to assure accurate readings.

   f. A reading of ___________________ indicates an open fuse, switch, or wire while a reading of _____________ ohms or very near ____________ ohms indicates continuity because the ohmmeter was able to send an electrical signal through the component.

   g. An open load will also have _______________________ resistance, but the proper ________________________ of a load can only be obtained from OEM specifications.

Written Test

h. Do not use an ohmmeter to test most solid-state devices because solid-state devices can be damaged by the ______________ ______________ of the meter.

9. Complete statements about checking for shorts and grounds. Write in the information that best completes each of the following statements.

   a. The symptoms for shorts and grounds are ______________ and technicians often confuse one with the other.

   b. A short occurs when electricity takes an ______________ path or ______________ such as when motor windings touch each other where they should not.

   c. A ground occurs when electricity takes a ______________ path to ground such as through an equipment case.

   d. Either a shorted or a grounded load will usually blow a fuse or trip a breaker because the current is allowed to flow without being ______________ by the designed load.

   e. Resistance readings of a shorted load are ______________ than OEM specifications.

   f. A shorted switch or shorted wiring will usually cause a load to ______________ to operate when it is not supposed to be operating.

   g. Check for a ground with an ohmmeter by placing one probe on the component and the other probe on a known ground such as the ______________ wire on a grounded cord or copper tubing in a refrigeration system.

10. Select true statements about using jumpers. Circle the number in front of the information that makes each of the following statements true.

   a. Since an open operating switch, open safety switch, or open wiring or connections will usually not allow a circuit or system to operate, the open may need to be:

      (1) permanently jumpered so the equipment will operate.

      (2) temporarily jumpered to find out if the rest of the circuit or system will operate.

   b. Be sure power is off or disconnected before using jumpers, and when restoring power to test the circuit:

      (1) make sure all connections are tight.

      (2) be prepared to turn power off quickly.

Written Test

c. If the load does not operate after using jumpers, use the hopscotch method to find additional opens, and if additional opens are found:

   (1) previous jumpers can be removed.

   (2) additional jumpers can be installed for any additional opens.

d. When checks are completed:

   (1) be sure to operate the equipment with the jumpers installed.

   (2) be sure to remove all jumpers.

11. Identify problems about troubleshooting techniques. Circle the number in front of the information that best identifies the problem in each of the following statements.

a. Since the process of elimination is the basic technique for most electrical troubleshooting, the technician needs to start with the right test instrument.

   (1) The problem is that the technican should first find out what the equipment **should** be doing and what it **is** doing.

   (2) The problem is that the technician should **first** check all sources of power.

b. To find what the equipment should be doing, a technician should rely on experience in the field.

   (1) The problem is that experience alone won't solve all problems: the technician needs equipment history and equipment wiring diagrams.

   (2) The problem is that the equipment owner has more knowledge about what the equipment should be doing than the technician does.

c. To find what the equipment is doing, a technician should rely on system observations and test results.

   (1) The problem is that observations and test results mean nothing unless the system wiring diagram is available for reference.

   (2) The problem is that the customer complaint should also be considered a good troubleshooting reference.

Written Test

d. The experiences of other technicians who have serviced similar problems are very useful in troubleshooting and these experiences are usually passed on orally from technician to technician.

   (1) The problem is that technicians often talk about procedures that they may not remember in detail.

   (2) The problem is that the troubleshooting experiences of other technicians are very useful, but their most useful form is in troubleshooting charts or tables that can be referenced as needed.

Permission to duplicate this test is granted.

Troubleshooting ACR System Electrical Circuits
Unit 14

Unit Evaluation Form

Name ______________________________ Date ___________ Overall Rating _____

Assignment Sheet 1—Identify Components on ACR System Electrical Diagrams Rating _______

Comments:

Assignment Sheet 2—Identify Component Operations from ACR Electrical Diagrams Rating _______

Comments:

Assignment Sheet 3—Select Test Instruments or Procedures for Specific ACR System Troubleshooting Rating _______

Comments:

Assignment Sheet 4—Solve ACR Electrical Troubleshooting Problems Rating _______

Comments:

Job Sheet 1—Troubleshoot Series Electrical Circuits on Selected ACR Equipment Rating _______

Comments:

Job Sheet 2—Troubleshoot Parallel Electrical Circuits on Selected ACR Equipment Rating _______

Comments:

Job Sheet 3—Troubleshoot Series-Parallel Electrical Circuits on Selected ACR Equipment Rating _______

Comments:

Unit Evaluation Form

Other:		
Written Test: ________	Pretest ________	Posttest ______ Total ______
Teacher Signature ______________________________		Date ______
Student Signature ______________________________		Date ______

Permission to duplicate this form is granted.

ACR System Wiring Diagrams
Unit 15

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction or individual learning activities. Study the specific objectives to determine the order in which you will present the objectives.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan enrichment of exceptional students as well as accommodation of special needs students.
4. Add overheads or other graphic materials as desired to enhance instruction.
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Evaluation

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Teaching Suggestions

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1. Have the entire class review "Unit 4, Circuits, Symbols, and Diagrams." Show students how basic circuitry functions in ACR system circuits. **Basic skills, science and listening.**

2. As you present component symbols in Objective 3, emphasize the difference in component symbols for pictorials and component symbols for ladder schematics. **Basic skills, science and listening.**

3. As you present switch symbols in Objective 4, emphasize the difference in switch symbols for pictorials and switch symbols for ladder schematics. **Basic skills, science and listening.**

4. Appoint student teams to find a pictorial and a matching ladder schematic from an ACR system. Have students report how symbols are used in the drawings, and have students note anything special presented in a legend. **Interpersonal skills, teamwork; Basic skills, speaking.**

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2. *The Air Conditioning, Heating and Refrigeration News HVAC/R Source Guide.* Troy, MI: Business News Publishing Company, 1995.

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http://www.hvaconline.com and **http://www.environ.com/hvacmall.htm**.

With certain membership requirements, both of these sites permit you to input questions about ACR service and receive answers from professionals in every area from installation to all kinds of troubleshooting. These sites can also be used to access news from professional HVAC organizations, some of which are listed here:

Air Conditioning and Refrigeration Institute—**http://www.ari.org**
Air Conditioning Contractors of America—**http://www.acca.org**
American Society of Heating, Refrigerating, and Air Conditioning Engineers—**http://www.ashrae.org**

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In their general training series, Carrier Training Services has several modules dedicated to the electrical elements of ACR training. *Module 9, Electrical Troubleshooting* is an excellent supplement for students and instructors alike, and the other eight texts in the series are equally well produced. The well executed series is enhanced with full color graphics and includes VHS videos, audio cassettes, and student workbooks. Quantity discounts are available for vo-tech schools and other training institutions. For a catalog of these and other materials from Carrier Training Services, write to:

Literature Services, Bldg. TR-8
P.O. Box 4808
Syracuse, NY 13221

Suggested Activities

Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process Evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product Evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review appropriate materials and submit another product for evaluation.

Option A

4—Can perform job with no additional training.
3—Moderately skilled—Has performed job during training program; limited additional training may be required.
2—Limited skill—Has performed job during training program; additional training is required to develop skill.
1—Unskilled—Is familiar with process but is unable to perform job.

Option B

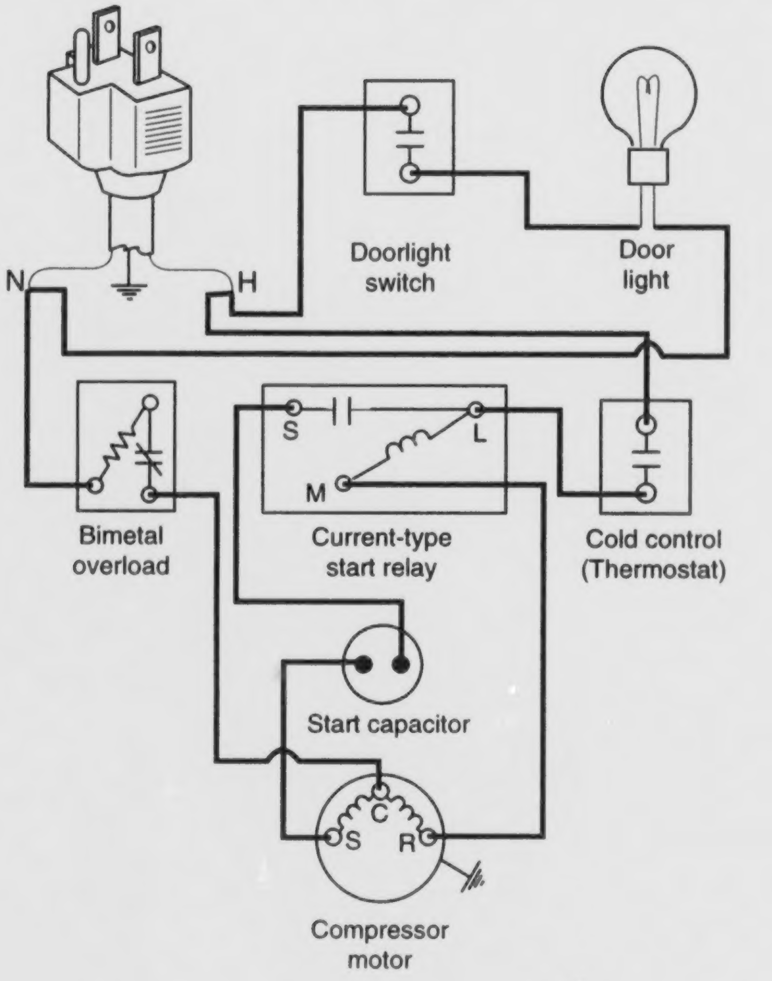
Yes—Can perform job with no additional training.
No—Is unable to perform job.

ACR System Wiring Diagrams
Unit 15

Answers to Assignment Sheets

Assignment Sheet 1

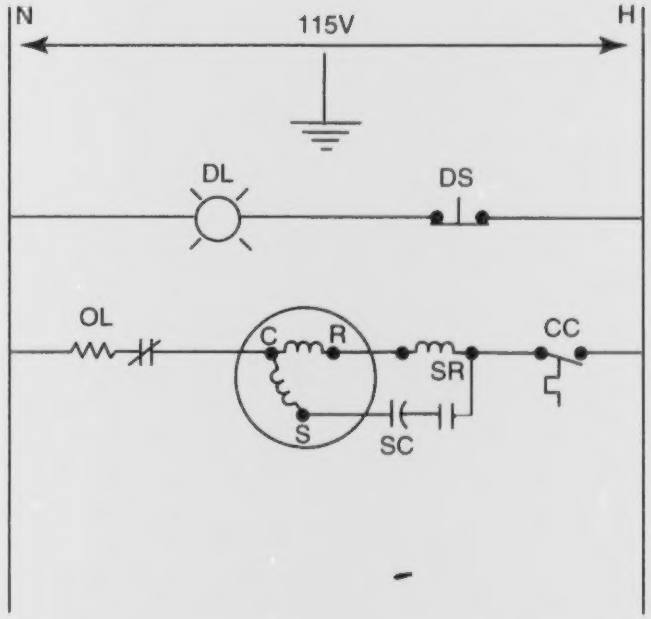
Pictorial


N
H
Doorlight switch
Door light
S
L
M
Bimetal overload
Current-type start relay
Cold control (Thermostat)
Start capacitor
C
S
R
Compressor motor

Answers to Assignment Sheets

Assignment Sheet 1

Ladder Schematic

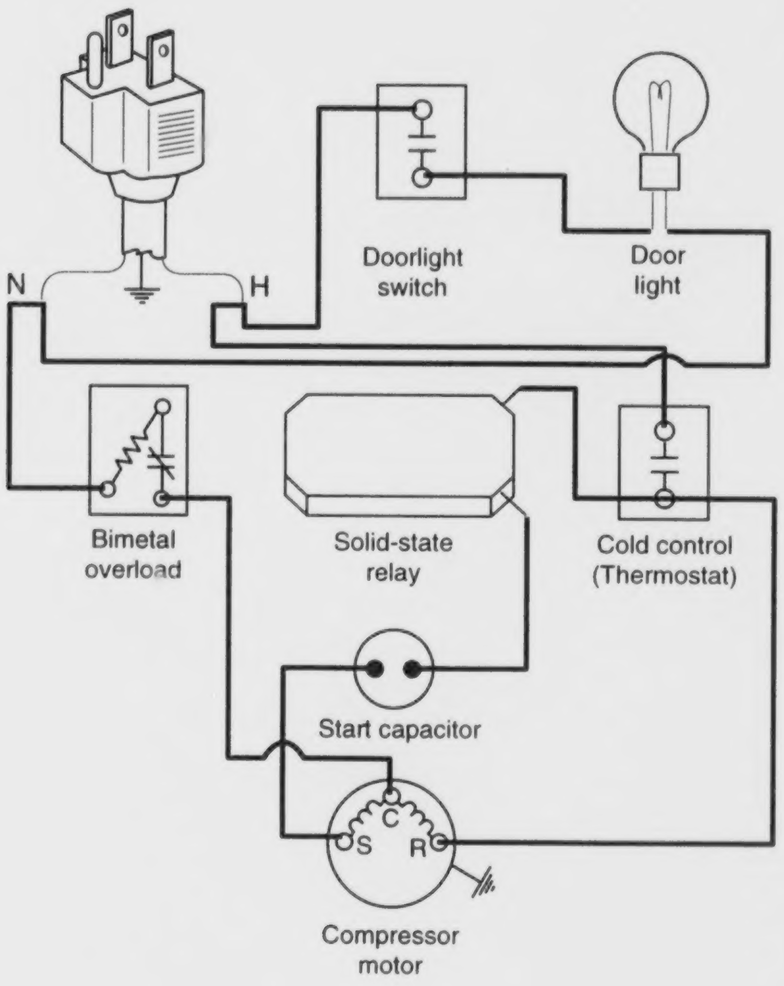

N
115V
H
DL
DS
OL
C
R
SR
CC
S
SC

304

Answers to Assignment Sheets

Assignment Sheet 2

Pictorial

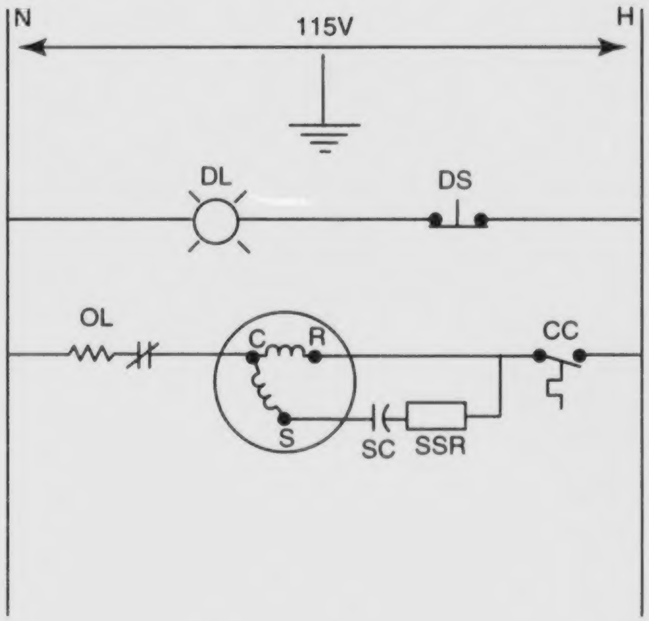

N
H
Doorlight switch
Door light
Bimetal overload
Solid-state relay
Cold control (Thermostat)
Start capacitor
C
S
R
Compressor motor

305

Answers to Assignment Sheets

Assignment Sheet 2

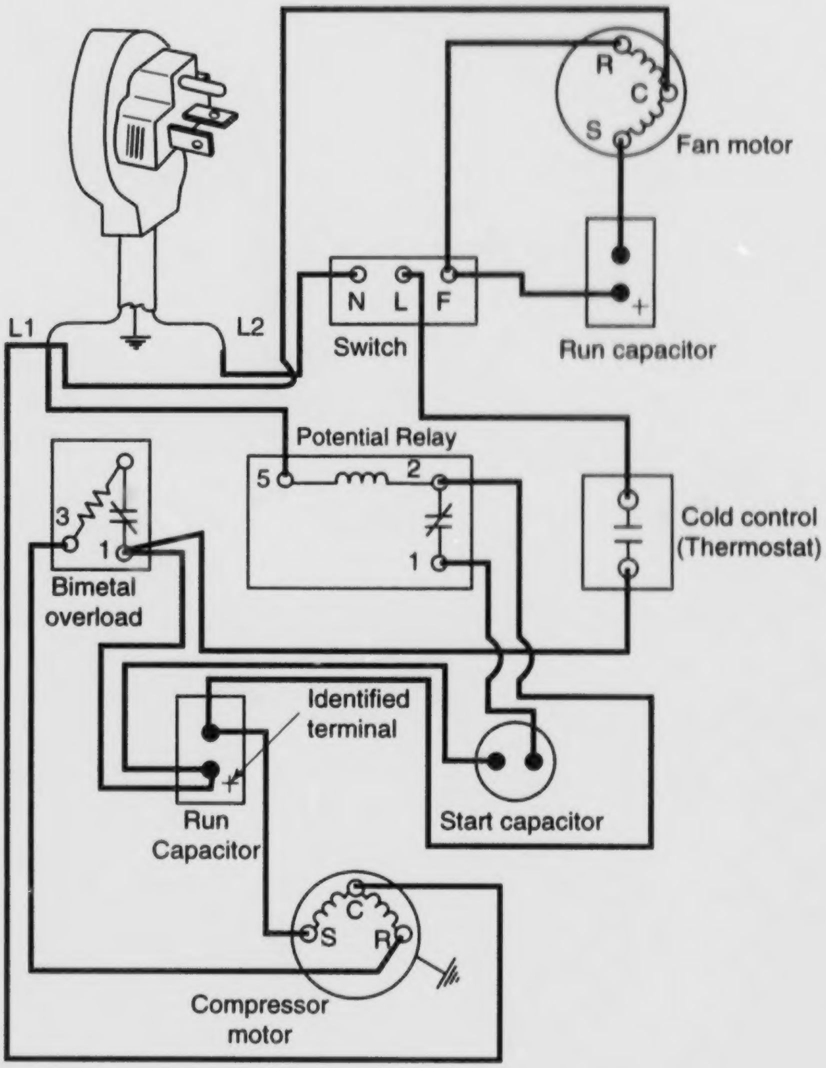
Ladder Schematic


N
115V
H
DL
DS
OL
C
R
S
CC
SC
SSR

Answers to Assignment Sheets

Assignment Sheet 3

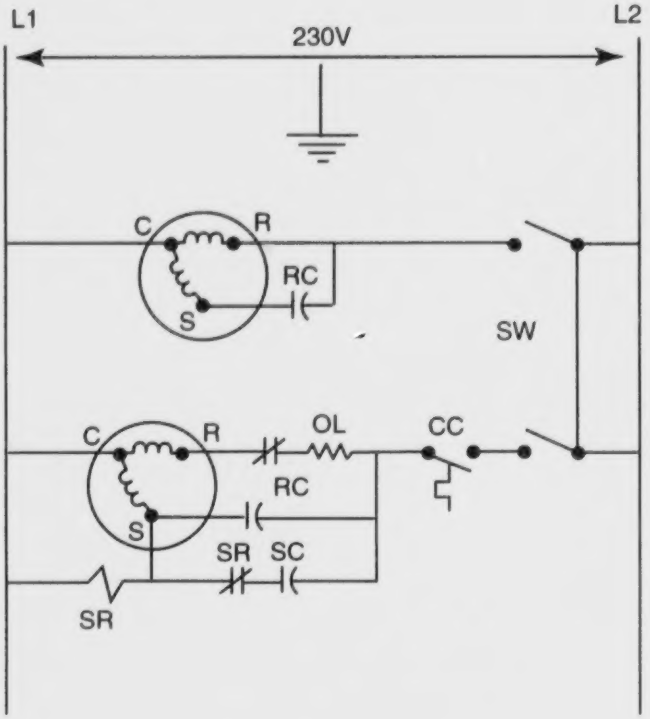
Pictorial


L1
L2
N
L
F
Switch
R
C
S
Fan motor
+
Run capacitor
Potential Relay
5
2
1
3
1
Bimetal overload
Cold control (Thermostat)
Identified terminal
+
Run Capacitor
Start capacitor
C
S
R
Compressor motor

Answers to Assignment Sheets

Assignment Sheet 3

Ladder Schematic

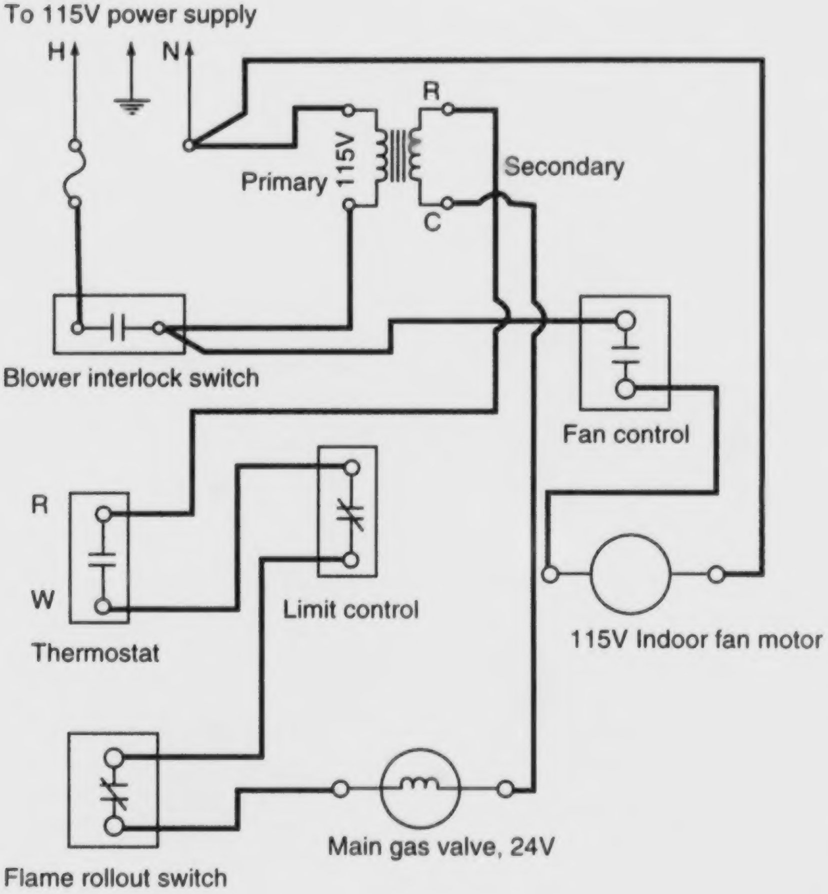

L1
L2
230V
C
R
RC
S
SW
C
R
OL
CC
RC
S
SR
SC
SR

308

Answers to Assignment Sheets

Assignment Sheet 4

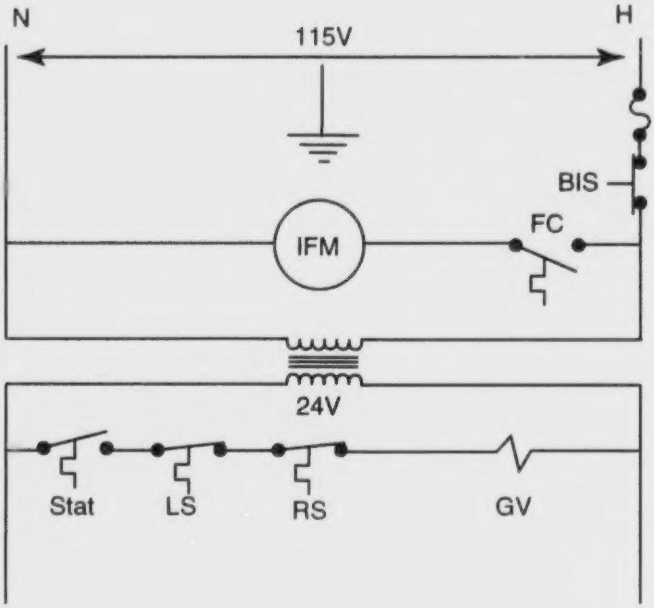
Pictorial


To 115V power supply
H
N
R
Primary
115V
Secondary
C
Blower interlock switch
Fan control
R
W
Thermostat
Limit control
115V Indoor fan motor
Flame rollout switch
Main gas valve, 24V

Answers to Assignment Sheets

Assignment Sheet 4

Ladder Schematic

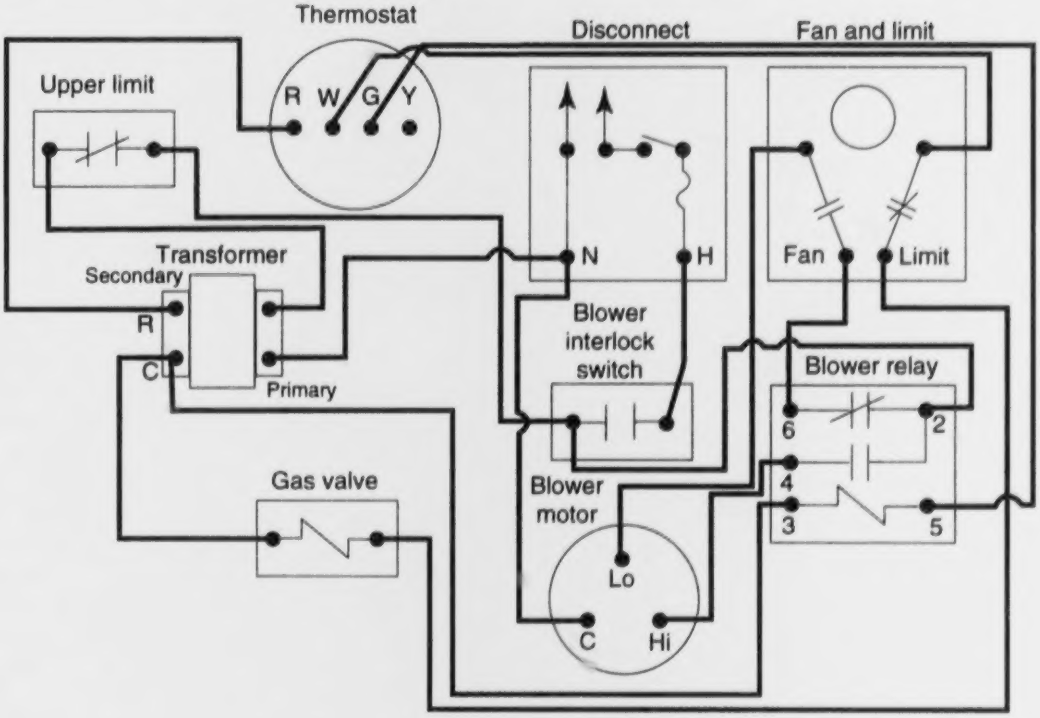

N
H
115V
BIS
FC
IFM
24V
Stat
LS
RS
GV

310

Answers to Assignment Sheets

Assignment Sheet 5

Pictorial

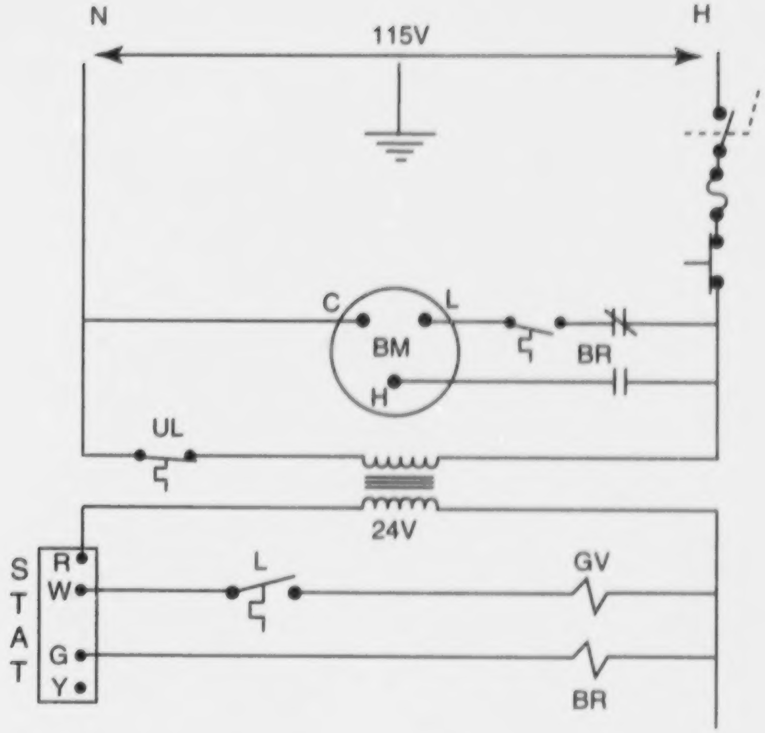

Thermostat
R
W
G
Y
Disconnect
Fan and limit
Upper limit
Transformer
Secondary
R
C
Primary
N
H
Fan
Limit
Blower
interlock
switch
Blower relay
6
2
4
3
5
Gas valve
Blower
motor
Lo
C
Hi

311

Answers to Assignment Sheets

Assignment Sheet 5

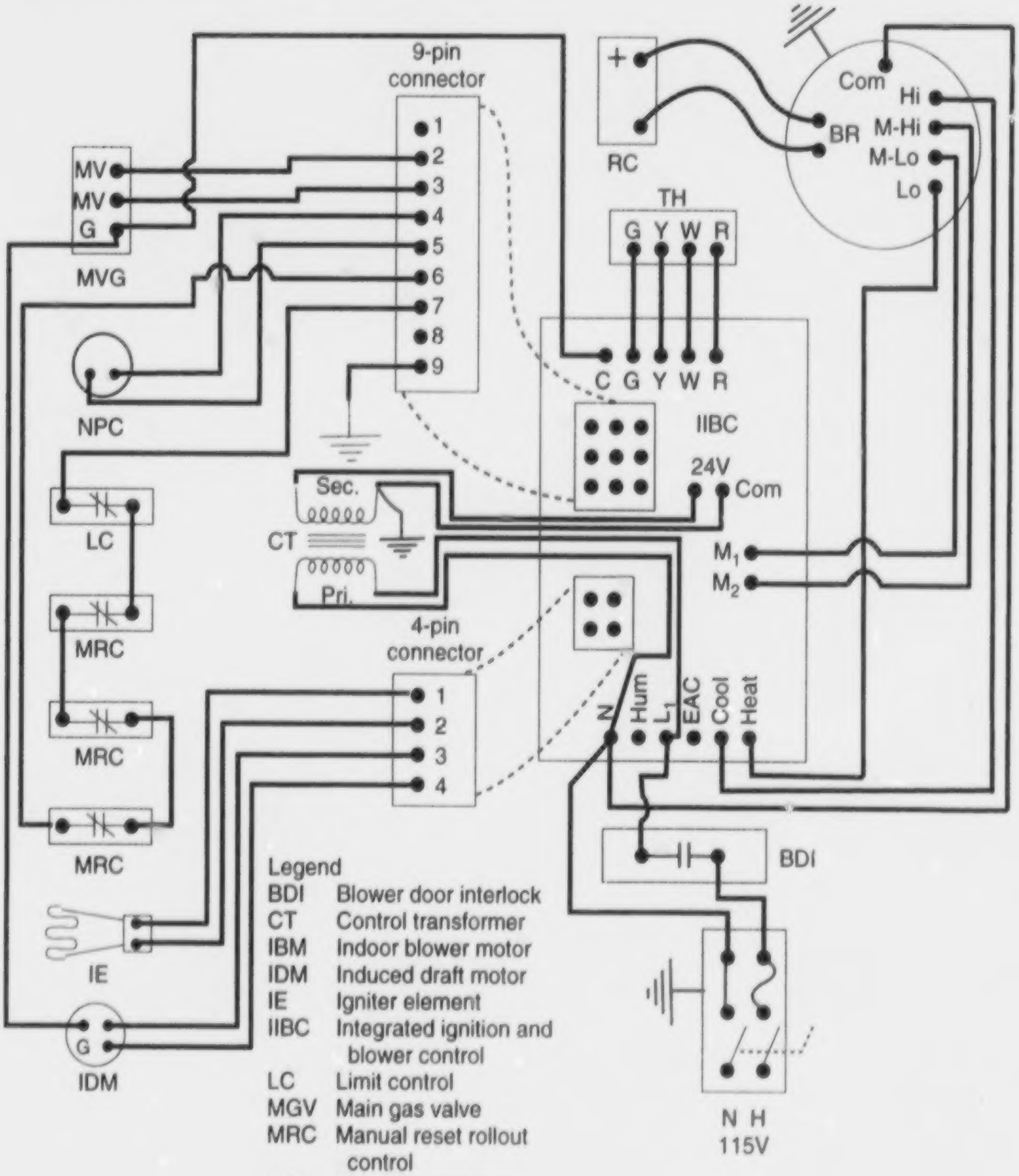
Ladder Schematic


N
H
115V
C
L
BM
H
BR
UL
24V
S
T
A
T
R
W
G
Y
L
GV
BR

Answers to Assignment Sheets

Assignment Sheet 6

Pictorial (no ladder schematic is required for this assignment)

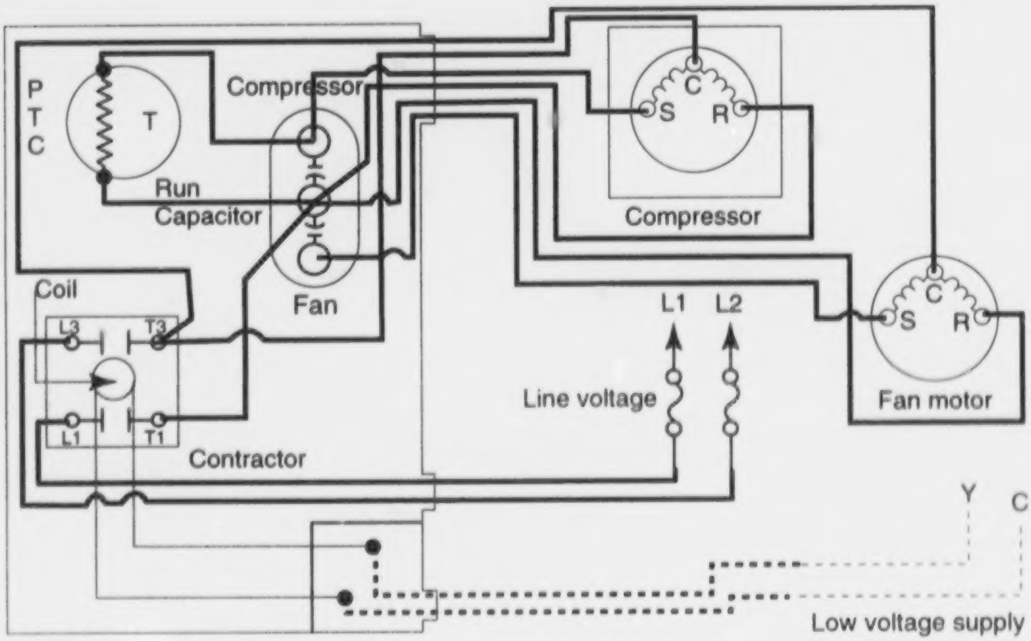

9-pin connector
1
2
3
4
5
6
7
8
9
MV
MV
G
MVG
NPC
LC
MRC
MRC
MRC
IE
G
IDM
Sec.
CT
Pri.
4-pin connector
1
2
3
4
+
RC
Com
Hi
M-Hi
M-Lo
Lo
BR
TH
G Y W R
C G Y W R
IIBC
24V
Com
M1
M2
N
Hum
L1
EAC
Cool
Heat
BDI
N H
115V

Legend	
BDI	Blower door interlock
CT	Control transformer
IBM	Indoor blower motor
IDM	Induced draft motor
IE	Igniter element
IIBC	Integrated ignition and blower control
LC	Limit control
MGV	Main gas valve
MRC	Manual reset rollout control
NPC	Negative pressure control
RC	Run capacitor
TH	Thermostat

Answers to Assignment Sheets

Assignment Sheet 7

Pictorial



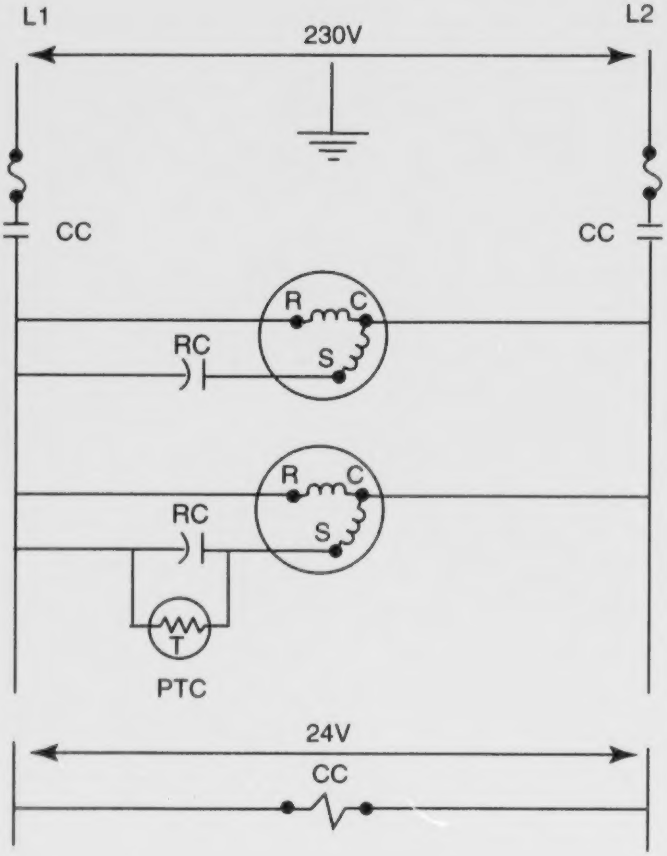
P
T
C
T
Compressor
Run
Capacitor
Fan
Compressor
C
S
R
Coil
L3
T3
L1
T1
Contractor
L1
L2
Line voltage
C
S
R
Fan motor
Y
C
Low voltage supply

314

Answers to Assignment Sheets

Assignment Sheet 7

Ladder Schematics

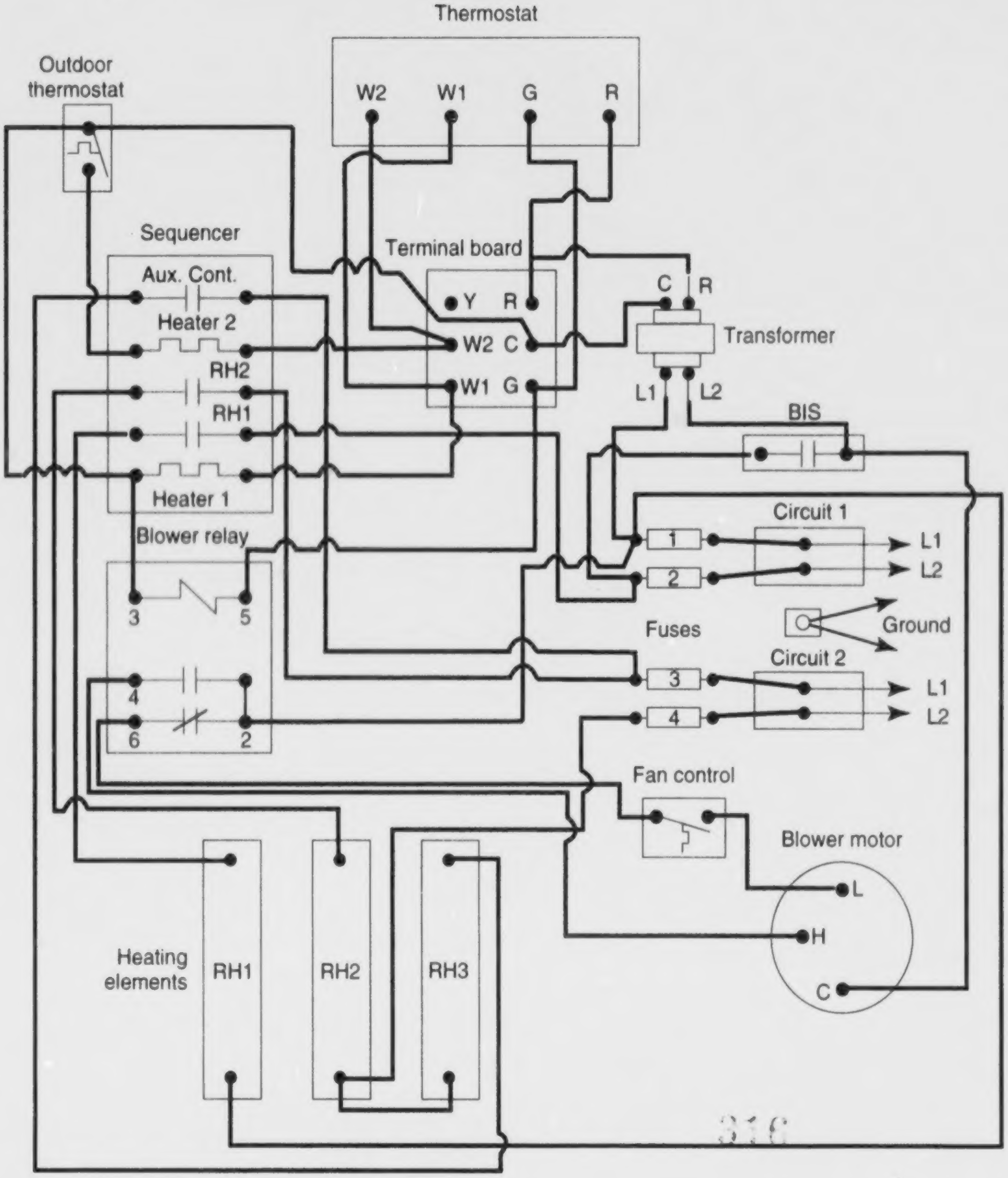

L1
230V
L2
CC
CC
R
C
RC
S
R
C
RC
S
T
PTC
24V
CC

315

Answers to Assignment Sheets

Assignment Sheet 8

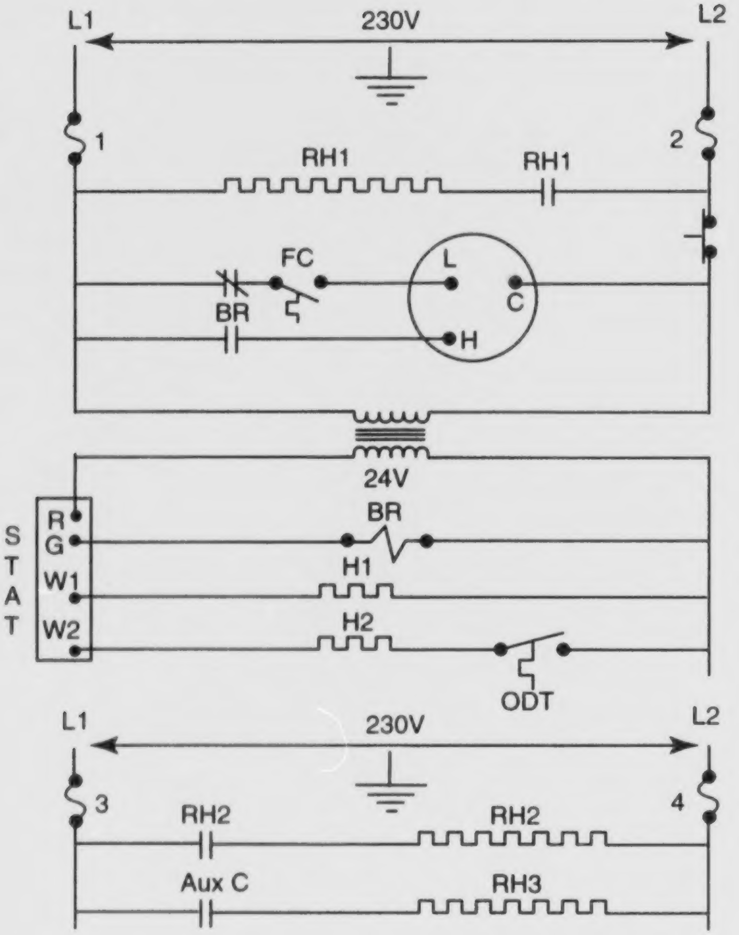
Pictorial


Thermostat
W2
W1
G
R
Outdoor thermostat
Sequencer
Aux. Cont.
Heater 2
RH2
RH1
Heater 1
Terminal board
Y
R
W2
C
W1
G
C
R
Transformer
L1
L2
BIS
Blower relay
3
5
4
6
2
Circuit 1
1
2
L1
L2
Fuses
Ground
Circuit 2
3
4
L1
L2
Fan control
Blower motor
L
H
C
Heating elements
RH1
RH2
RH3

Answers to Assignment Sheets

Assignment Sheet 8

Ladder Schematics

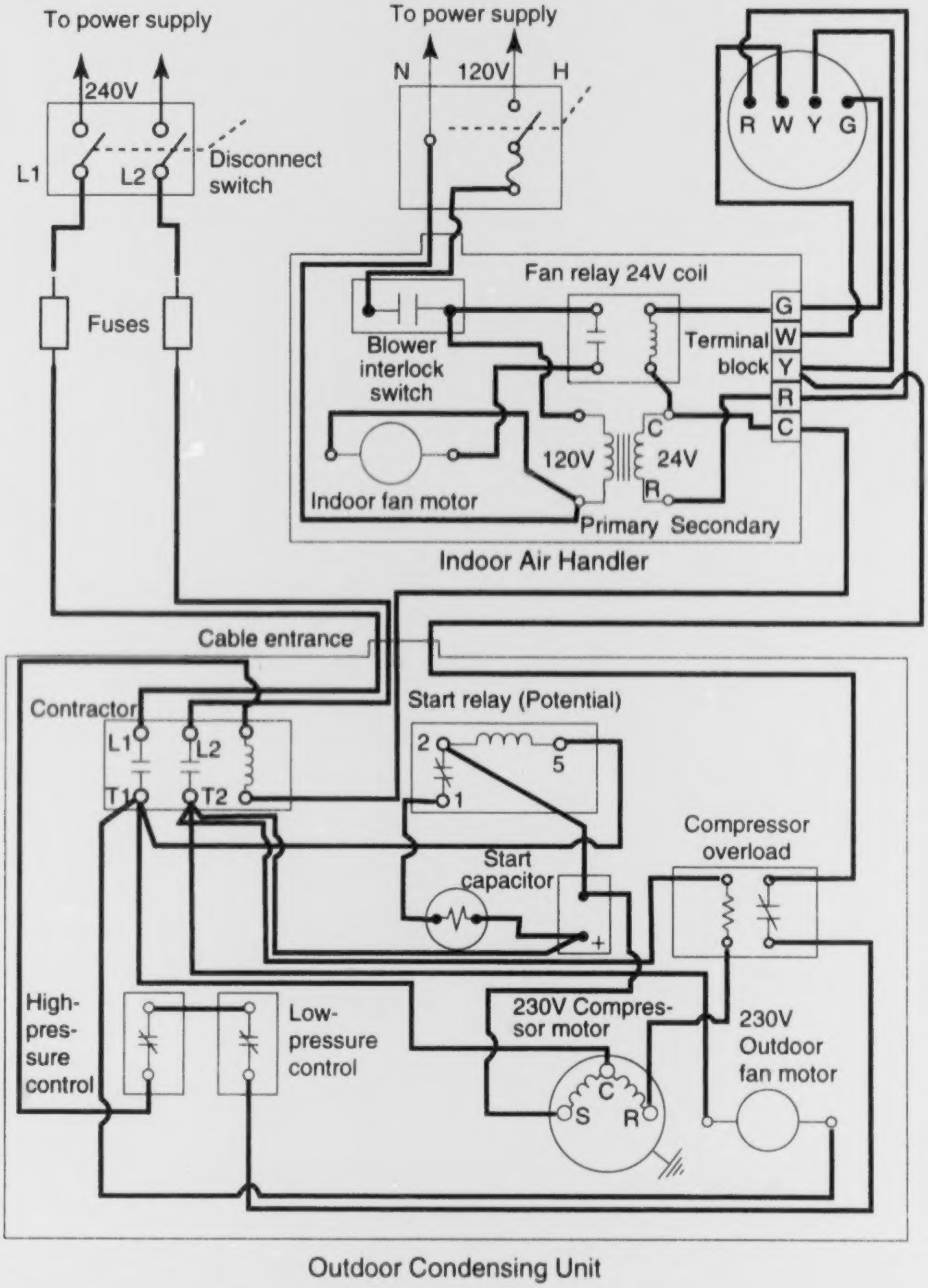


L1
230V
L2
1
2
RH1
RH1
FC
L
C
BR
H
24V
S
T
A
T
R
G
W1
W2
BR
H1
H2
ODT
L1
230V
L2
3
4
RH2
RH2
Aux C
RH3

Answers to Assignment Sheets

Assignment Sheet 9

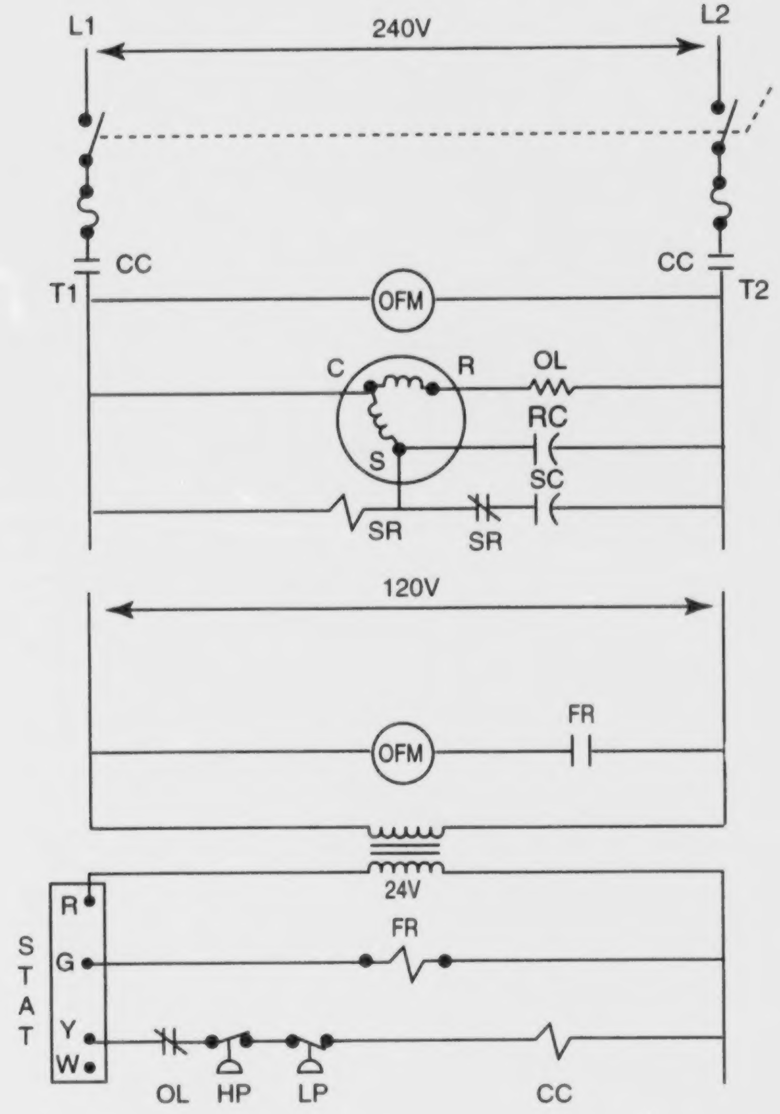
Pictorial


To power supply
240V
L1
L2
Disconnect switch
Fuses
To power supply
N
120V
H
R W Y G
Fan relay 24V coil
Blower interlock switch
Terminal block
G
W
Y
R
C
C
120V
24V
R
Indoor fan motor
Primary
Secondary
Indoor Air Handler
Cable entrance
Contractor
L1
L2
T1
T2
Start relay (Potential)
2
5
1
Start capacitor
+
Compressor overload
High-pressure control
Low-pressure control
230V Compressor motor
C
S
R
230V Outdoor fan motor
Outdoor Condensing Unit

Answers to Assignment Sheets

Assignment Sheet 9

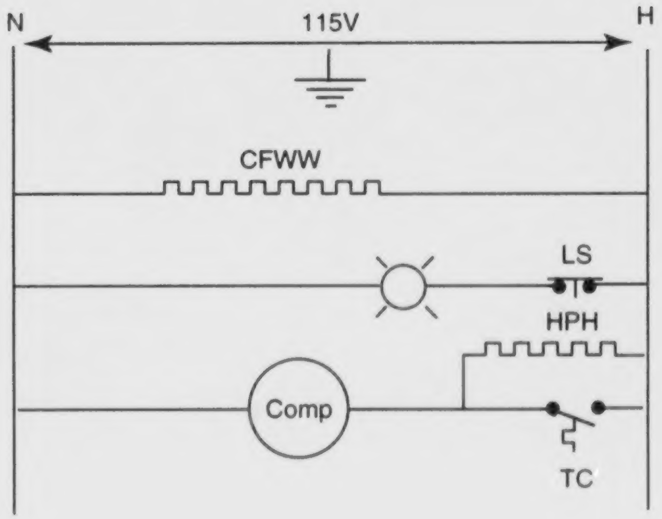
Ladder Schematics


L1
240V
L2
CC
CC
T1
T2
OFM
C
R
OL
RC
S
SC
SR
SR
120V
FR
OFM
24V
R
FR
S
T
A
T
G
Y
W
OL
HP
LP
CC

Answers to Assignment Sheets

Assignment Sheet 10

Ladder Schematic


N
115V
H
CFWW
LS
HPH
Comp
TC

320

ACR System Wiring Diagrams
Unit 15

Answers to Written Test

1. a. ladder schematic diagram
   b. pictorial diagram
   c. legend

2. a. recreate
   b. schematic
   c. symbols, symbols
   d. legend

3. a. 13
   b. 6
   c. 2
   d. 17
   e. 16
   f. 10
   g. 14
   h. 12
   i. 9
   j. 5
   k. 3
   l. 7
   m. 15
   n. 11
   o. 8
   p. 1
   q. 18
   r. 4

4. a. 3
   b. 9
   c. 11
   d. 7
   e. 2
   f. 6
   g. 1
   h. 10
   i. 5
   j. 8
   k. 4

5. a. 5
   b. 2
   c. 4
   d. 1
   e. 6
   f. 3

6. a. (2)
   b. (2)

ACR System Wiring Diagrams
Unit 15

Written Test

Name________________________________ Date ________ Score_______

1. Complete statements about terms and definitions. Write in the word(s) that best completes each of the following definitions.

   a. A diagram which resembles a ladder and which shows electrical components as symbols, how they function, and their order of operation is called a ______________ ________________ ______________.

   b. A diagram which shows pictures or representative drawings of electrical components in their approximate locations in the equipment is called a ______________ ______________.

   c. The descriptive list of the components in a wiring diagram is called a ______________.

2. Complete statements about guidelines for drawing system diagrams. Write in the information that best completes each of the following statements.

   a. When system wiring diagrams are gone or unreadable, a service technician must sometimes ______________ a wiring diagram before troubleshooting or repairing system wiring.

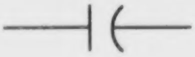
   b. Technicians usually choose to draw a ______________ diagram because it shows the functions of components and order of operations.

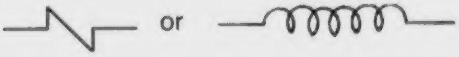
   c. Pictorial diagram graphics or ____________ must be converted to schematic ____________ in a schematic drawing.

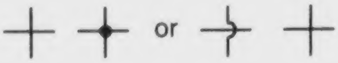
   d. If no pictorial is available or there could be some confusion over the identity of a component, it will be labeled or identifed in a ____________.

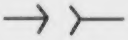
Written Test

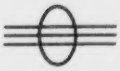
3. Match ACR components with their schematic symbols. Place the number beside the component in the blank beside its schematic symbol.

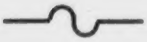
__ a. 

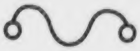
__ b. 

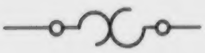
__ c. 

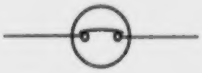
__ d. 

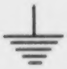
__ e. 

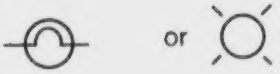
__ f. 

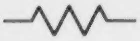
__ g. 

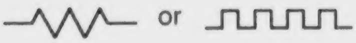
__ h. 

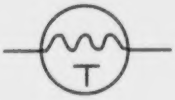
__ i. 

__ j. 

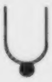
__ k. 

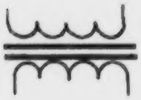
__ l. 

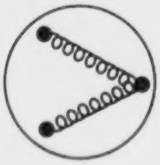
__ m. 

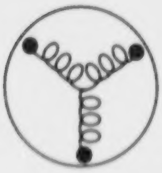
__ n. 

1. Transformer
2. Conductors
3. Light
4. Three-phase motor
5. Ground connection
6. Coil
7. Resistor
8. Thermocouple
9. Bimetal disc
10. Fuse
11. Thermistor
12. Thermal overload
13. Capacitor
14. Fusible link
15. Resistance heater
16. Multiple conductor cable
17. Connectors
18. Single-phase motor

__ o. 

__ p. 

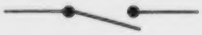
__ q. 

__ r. 

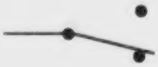
Written Test

4. Match ACR system switches with their schematic symbols. Place the number beside the switch in the blank beside its schematic symbol.

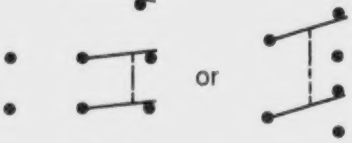
__ a.



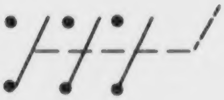
__ b.



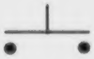
__ c.



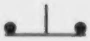
__ d.



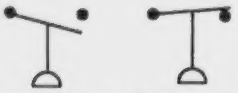
__ e.



__ f.

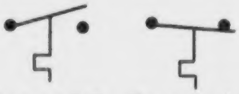


__ g.



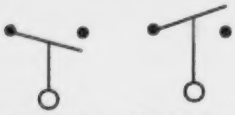
Close on rise Open on rise

__ h.



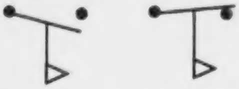
Close on fall Open on fall

__ i.



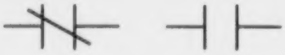
Close on rise Close on fall

__ j.



Close on increase Open on increase

__ k.

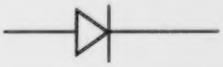
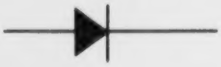


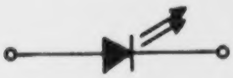
NC NO

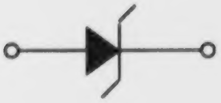
1. Pressure switches
2. Push button NO
3. SPST switch
4. Contacts
5. Liquid level switches
6. Push button NC
7. TPST Disconnect
8. Flow switches
9. SPDT switch
10. Temperature switches
11. DPDT switch

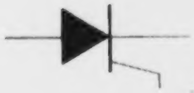
Written Test

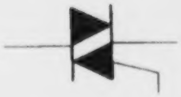
5. Match solid-state components with their schematic symbols. Place the number beside the component in the blank beside its schematic symbol.

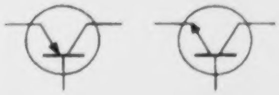
__a.  or 

__b. 

__c. 

__d. 

__e. 

__f. 

1. SCR
2. LED
3. Transistor
4. Zener diode
5. Diode
6. Triac

6. Select true statements about the procedure for drawing typical ACR system wiring diagrams. Circle the number in front of the information that makes each of the following statements true.

   a. When a technician draws a pictorial of an ACR system, the final drawing should show:

      (1) connections and operations of components.

      (2) pictures or sketches of component symbols with connections drawn in.

   b. The pictorial is actually a good reference for a technician to use for drawing a:

      (1) schematic that shows the location of all components.

      (2) a ladder schematic that shows how components operate, and using special symbols designed for ladder schematics.

Permission to duplicate this test is granted.

ACR System Wiring Diagrams
Unit 15

Unit Evaluation Form

Name ______________________________ Date ___________ Overall Rating _____

Assignment Sheet 1—Draw Wiring Diagrams for a Refrigerator With a Coil-Type Current Relay Comments:	Rating _____
Assignment Sheet 2—Draw Wiring Diagrams for a Refrigerator With a Solid-State Start Relay Comments:	Rating _____
Assignment Sheet 3—Draw Wiring Diagrams for a Window Air Conditioner Comments:	Rating _____
Assignment Sheet 4—Draw Wiring Diagrams for a Standard Upflow Gas Furnace Comments:	Rating _____
Assignment Sheet 5—Draw Wiring Diagrams for a Standard Downflow Gas Furnace Comments:	Rating _____
Assignment Sheet 6—Draw Wiring Diagrams for a Multi-position Gas Furnace With an Integrated Control Board Comments:	Rating _____
Assignment Sheet 7—Draw Wiring Diagrams for a Condensing Unit Comments:	Rating_____

Unit Evaluation Form

Assignment Sheet 8—Draw Wiring Diagrams for an Electric Furnace Rating_____

Comments:

Assignment Sheet 9—Draw Wiring Diagrams for a Condensing Unit and an Air Handler Rating _____

Comments:

Assignment Sheet 10—Draw a Ladder Schematic for a Domestic Refrigerator Rating _____

Comments:

Job Sheet 1—Observe a Domestic Refrigerator and Draw a Ladder Schematic of Its Electrical Circuits Rating _____

Comments:

Job Sheet 2—0bserve a Window Air Conditioner and Draw a Ladder Schematic of Its Electrical Circuits Rating _____

Comments:

Job Sheet 3—Observe a Heating/Cooling System With 24V Controls and Draw a Ladder Schematic of Its Electrical Circuits Rating _____

Comments:

Other:

Written Test: __________ Pretest _______ Posttest _______

Total _______

Teacher Signature ____________________________________ Date __________

Student Signature ____________________________________ Date __________

Permission to duplicate this form is granted.

A/C/R Electrical Systems

Student Edition

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MAVCC

Multistate Academic and Vocational Curriculum Consortium

ACR Electrical Systems

Student Edition

Written by

Mark Clemons

Project Coordinated by

Dan Fulkerson
Curriculum Specialist

Developed by

The Multistate Academic and Vocational Curriculum Consortium
1500 West Seventh Avenue
Stillwater, Oklahoma 74074-4364

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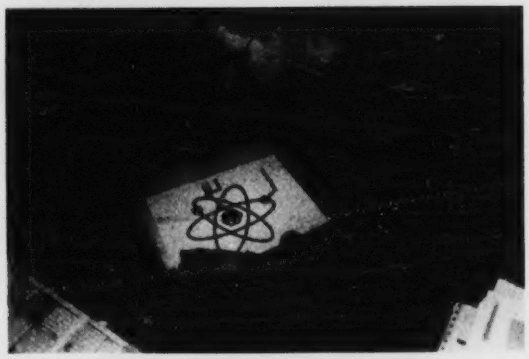


Fundamentals of Electricity

Unit 1

Objective Sheet

Unit Objective

After completing this unit, the student should be able to convert electrical measurements to basic units and use Ohm's Law to determine unknown values in resistive circuits. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to fundamentals of electricity with their correct definitions.
2. Complete statements about electricity.
3. Identify sources of electricity and their characteristics.
4. Select true statements about the electron theory.
5. Complete statements about the importance of electrical charges.
6. Complete statements about how current is caused to flow in a circuit.
7. Complete statements about insulators, semiconductors, and conductors.
8. Select true statements about direct current.
9. Complete statements about alternating current.
10. Solve problems about electrical loads.
11. Sketch a basic electrical circuit.
12. Identify basic electrical symbols.
13. Identify the three types of circuits.
14. Select true statements about circuit grounding.
15. Complete statements about electrical measurements.

Objective Sheet

16. Define terms and definitions used in rules governing electricity.

17. Write the three equations for using Ohm's Law.

18. Complete statements about using Ohm's Law to find unknown values.

19. Complete statements about using Ohm's Law to determine values in a series circuit.

20. Complete statements about using Ohm's Law to determine values in a parallel circuit.

21. Complete statements about using Ohm's law to determine values in a series parallel circuit.

22. Complete statements about applications of electronics in ACR control systems.

23. Convert electrical measurements to basic units. (Assignment Sheet 1)

24. Use Ohm's Law to determine unknown values in resistive circuits. (Assignment Sheet 2)

Fundamentals of Electricity
Unit 1

Information Sheet

1. **Terms and definitions**

   a. **AC**—Alternating current, an electrical current that reverses its direction of flow at regular intervals

   b. **Circuit**—A path for electrical current that completes a loop

   c. **DC**—Direct current, a current that travels in one direction only

   d. **Electricity**—That branch of science that deals with the phenomena of electric energy and its applications

   e. **Electronics**—In electrical circuitry, the application of small, solid-state components capable of performing a multitude of functions at a high rate of speed

   f. **Frequency**—The number of times something happens in a given period of time as in the cycling of alternating current

   g. **Mathematical notation**—The use of superscript numbers such as 10^6 to indicate ten to the sixth power or the use of subscript numbers to indicate order or other information such as R_1 for resistor 1 or R_T for total resistance

   h. **Metric**—An international system of measurement

   i. **Solid-state**—Electrical circuits containing semiconductors

2. **Electricity**

   a. Electricity is a form of energy that can be converted to light, heat, or mechanical action to perform useful work.

   b. Electricity exists in nature as static electricity and as lightning, but these forms of energy do not perform useful work.

   c. Electricity used for domestic and industrial purposes is generated at power plants and transmitted by high voltage power lines to towns and cities.

   d. High voltage electricity from a generating plant usually has to go through a transformer that steps it down to a lower voltage for home and industry use.

   e. In the average home, electricity is put to work in an arrangement of parallel circuits to supply electricity for lighting, heating, air conditioning, and appliance use.

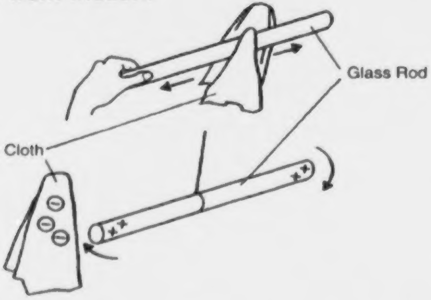
   f. To benefit people, electricity has to be controlled, and switches, relays, transformers and other control devices are what make air conditioning and refrigeration equipment useful for modern living.

Information Sheet

3. Sources of electricity and their characteristics

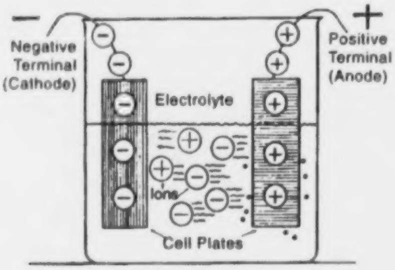
a. **Friction** produces static electricity when two materials are rubbed together.

Example: You can build up static electricity from friction just by walking across a wool or nylon carpet. In fact, touch a door handle after crossing a carpet and you could experience a mild static shock. Rubbing a glass rod with a silk cloth also produces electricity from friction.



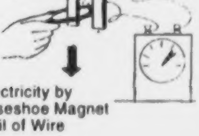
b. **Chemical reaction** produces direct current electricity in batteries and cells when dissimilar elements are placed in a chemical which acts upon them.

Example: Flashlight batteries and car batteries both use chemical reaction to produce electricity.

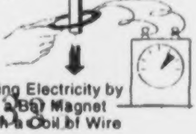


c. **Magnetism** produces direct current or alternating current electricity by moving a conductor through a magnetic field

Example: Generators use the principle of magnetism to produce electricity.



Producing Electricity by Moving a Horseshoe Magnet Through a Coil of Wire

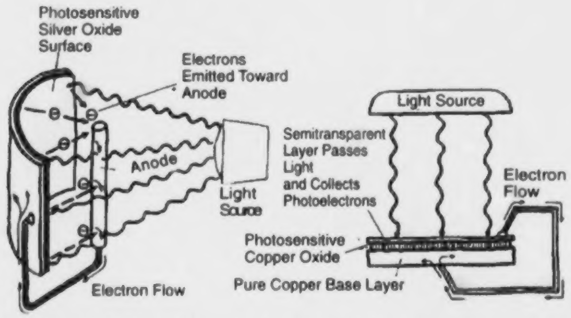


Producing Electricity by Moving a Bar Magnet Through a Coil of Wire

Information Sheet

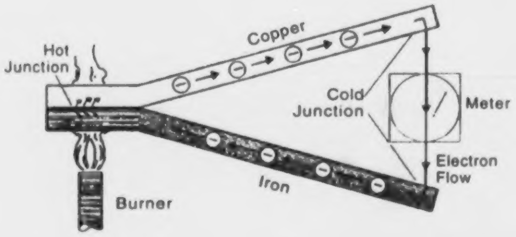
d. **Photoelectric surfaces** produce electricity when light strikes them.

Example: Solar cells in space craft and photovoltaic cells in some calculators both produce electricity from light.


Photosensitive Silver Oxide Surface
Electrons Emitted Toward Anode
Anode
Light Source
Electron Flow
Light Source
Semitransparent Layer Passes Light and Collects Photoelectrons
Electron Flow
Photosensitive Copper Oxide
Pure Copper Base Layer

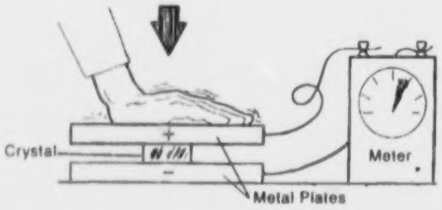
e. **Heat** produces electricity whens it is applied to two dissimilar metals that are next to each other.

Example: Thermocouples such as those used on gas heating equipment and many other types of thermocouples produce electricity from heat.


Hot Junction
Copper
Cold Junction
Meter
Electron Flow
Iron
Burner

f. **Mechanical pressure** produces electricity when applied to certain crystalline substances.

Example: The crystal in a record player needle produces an electrical signal as a result of pressure between the record and the needle.


+
Crystal
−
Meter
Metal Plates

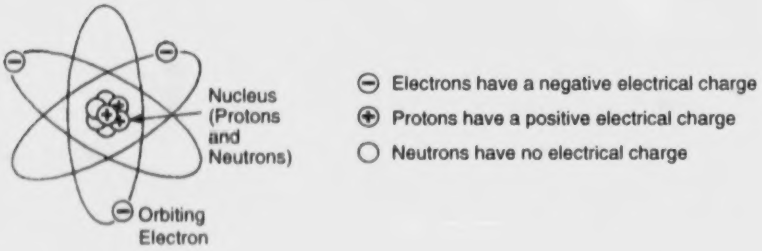
Information Sheet

4. The electron theory

a. Understanding electricity requires basic knowledge of the structure of an atom.

b. The nucleus of an atom is made up of neutrons with no electrical charge and protons which have electrical positive charges.

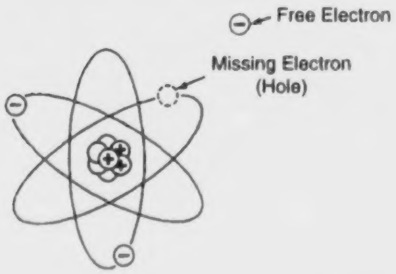
c. Electrons with negative charges orbit the nucleus in paths that are called shells.

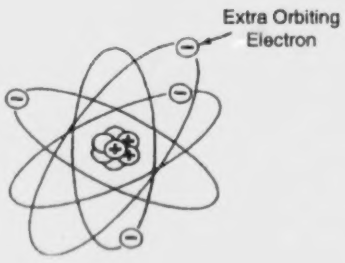

Nucleus (Protons and Neutrons)
Orbiting Electron
⊖ Electrons have a negative electrical charge
⊕ Protons have a positive electrical charge
○ Neutrons have no electrical charge

d. Electrons that orbit in inner shells are attracted to the nucleus, but electrons in the outer shell or "valence shell" can be set free.

e. When energy is applied to the centrifugal force in an electron, the electron leaves its previous orbit and moves to a higher orbit.

f. Since a valence electron has no higher orbit, it will leave the parent atom and move to another atom.


Free Electron
Missing Electron (Hole)


Extra Orbiting Electron

g. The negative charge of an electron freed from the valence shell is the basic unit of electricity.

Information Sheet

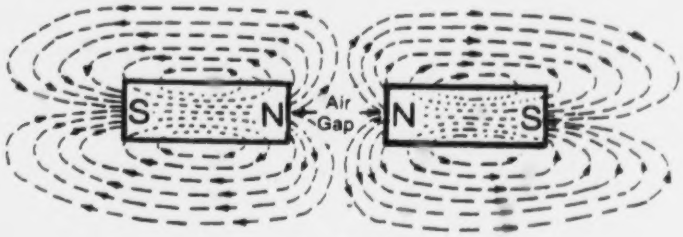
5. The importance of electrical charges

a. In his experiments with electrical charges, a Frenchman named Charles Coulomb formulated a law that governs the interaction of negative and positive charges.

b. The two most important electrical relationships established by Coulomb are:

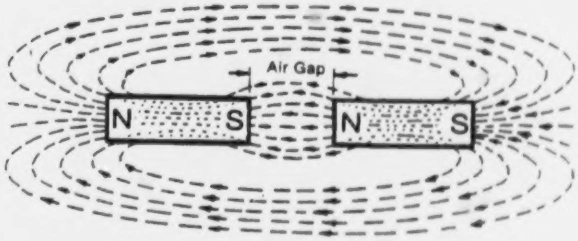
(1) like charges repel.

Example: A negative charge repels another negative charge.



(2) unlike charges attract.

Example: A positive charge attracts a negative charge.



c. The fact that positive charges attract negative charges is extremely important to the movement of electrons required to create current flow in a conductor.

d. The application of the attraction and repulsion principle helps make AC and DC motors perform useful work.

6. **How current is caused to flow in a circuit**

   a. To create electron or current flow through a conductor requires a source of already energized electrons such as those found in a power source like a battery.

   b. The wire or medium that serves as the conductor must have one end connected to the negative side of the power source and the other end connected to the positive end of the power source.

   c. Negative charges in the power source energize negative charges in the conductor and cause those negative charges to start moving through the conductor.

      Note: Remember that Coulomb's Law states that like charges will repel each other.

   d. The positive charges at the other end of the power source attract the electrons from the negative side of the power source, and this attraction reinforces electron flow.

   e. The presence of negative charges at one end of a conductor and the absence of negative charges at the other end of the conductor sets up a situation called a "potential difference."

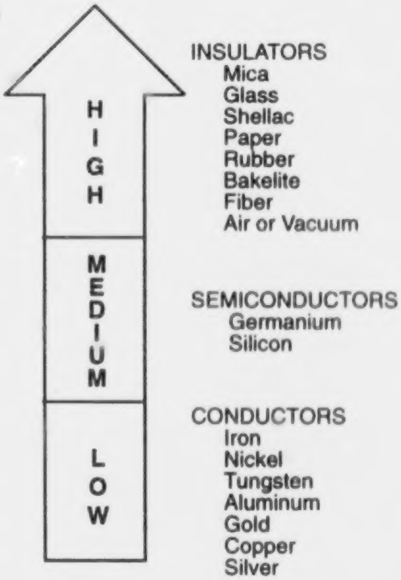
   f. A "potential difference" must be present before electrons will flow in a conductor to create electric current that can be put to work.

7. **Insulators, semiconductors, and conductors**

   a. Materials whose atoms have valence electrons strongly attached to the parent atom have high resistance to current flow and make good insulators.

   b. Materials whose atoms have valence electrons that are only moderately attached to the parent atom can have their resistance manipulated to be high or low, and these materials make good semiconductors.

   c. Materials that have only one or very few valence electrons have little resistance to current flow and make good conductors.


HIGH
MEDIUM
LOW
INSULATORS
Mica
Glass
Shellac
Paper
Rubber
Bakelite
Fiber
Air or Vacuum
SEMICONDUCTORS
Germanium
Silicon
CONDUCTORS
Iron
Nickel
Tungsten
Aluminum
Gold
Copper
Silver

Information Sheet

8. Direct current

a. The most common source of direct current electricity is the battery.

b. Both wet and dry cell batteries operate on the same principle of two dissimilar metals placed in a chemical that reacts upon them.

Note: A liquid electrolyte is used in a wet cell battery, and a chemical paste is used in a dry cell batttery.

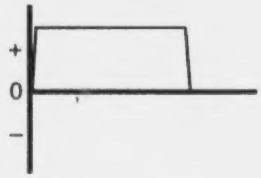
c. Chemical reaction in a battery creates a potential difference between dissimilar elements and creates a condition for electron flow.

d. Potential difference is also called "voltage" and can be tapped into with wires and directed to an electrical device; this electrical device which uses electricity is called a "load."

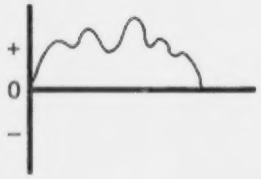
e. The essential characteristic of direct current is that the strength of the current may rise or fall, but it never becomes negative.

f. When plotted graphically to depict its movement in time, direct current may be:

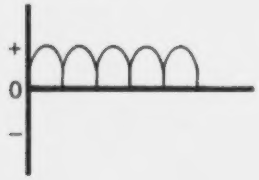
(1) Nonfluctuating.



(2) Fluctuating.



(3) Pulsating.



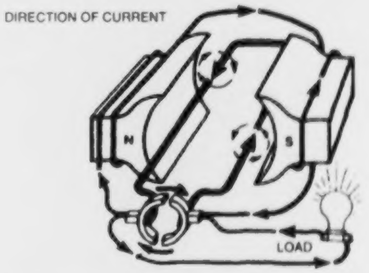
g. Direct current is used in many solid-state and electronic control devices.

Information Sheet

9. Alternating current

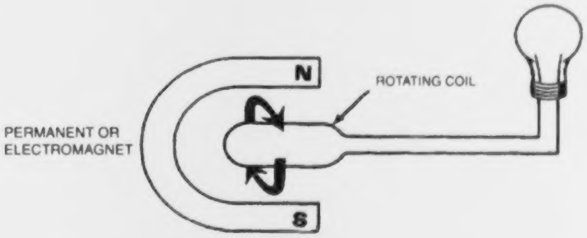
a. Alternating current is most often produced by a generator which uses the principle that a magnetic field can cause current to flow in a conductor.

b. This is accomplished by first placing the conductor in a magnetic field and then putting either the conductor or the magnetic field in motion.


DIRECTION OF CURRENT
N
S
LOAD

c. When current is produced in this manner, we say that current is induced in the wire.

d. This is done in a simple generator by rotating a coil of wire in a magnetic field.


N
ROTATING COIL
PERMANENT OR ELECTROMAGNET
S

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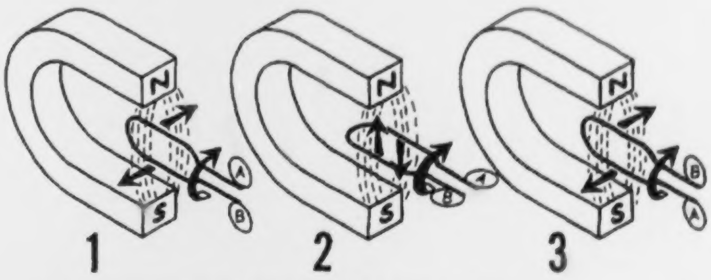
e. As a coil rotates in a magnetic field, it continually changes its direction with respect to the field, which means that it cuts the maximum number of force lines when it is parallel to the field and cuts no force lines when it is perpendicular to the field.


N
S
A
B
1
N
S
A
B
2
N
S
B
A
3

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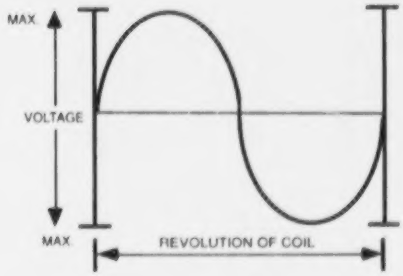
Information Sheet

f. As the coil rotates, voltage continually rises to the maximum level, drops to zero, then rises to the maximum again, and current reverses itself with each half revolution.



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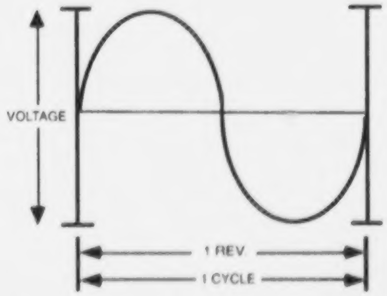
g. Alternating current is identified by its frequency which is determined by the number of revolutions of the coil in one second; each complete revolution of the coil equals one cycle.



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h. Most household current in the U.S. reverses itself 120 times per second, which means the voltage rises to 120 volts, then drops back to zero each half cycle, so there are 60 cycles per second or 60 hertz per second.

Note: Hertz is usually abbreviated to Hz, and when 60 Hz appears on an appliance or a motor, it means the device is designed to run on normal household current.

i. Alternating current can be transmitted from generating sources over long distances without excessive power loss, and is preferred over direct current.

Note: In some countries, AC is less than 60 Hz, and electrical devices may have to be modified to operate at the lower frequency.

Information Sheet

10. **Electrical loads**

    a. Practical use of electricity is acomplished through the use of electrical loads which may be resistive or inductive.

    b. Resistive loads such as resistors, lights, and heating elements convert electricity into heat or light.

    c. Inductive loads such as relay coils and motors convert electricity into mechanical motion.

    Note: Relays will be covered in Unit 6, and Motors will be covered in Units 10 through 15.

11. **Basic electrical circuits**

    a. A basic circuit is a source of electricity connected to the load(s) it powers.

    b. A complete circuit must have:

        (1) a power source such as a battery, a generator, or connection to power supplied from such a source.

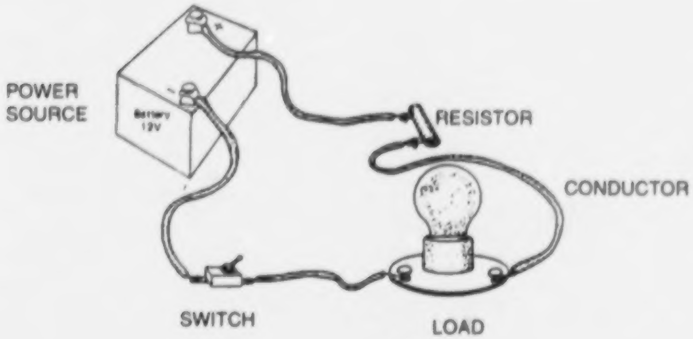
        (2) one or more loads such as light bulbs, motors, or resistors.

        (3) conductors such as metal wires or strips of metal to connect the source to the load(s).

    c. To be of practical use, a circuit should also have:

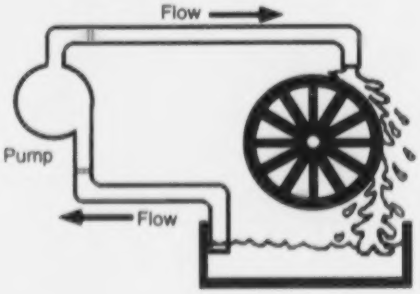
        (1) one or more devices such as switches to interrupt the circuit when desired.

        (2) one or more specialized switches such as fuses or circuit breakers to act as protection devices which will interrupt the circuit when something goes wrong.



Information Sheet

d. Think of a basic electrical circuit as a water circuit in which water is pumped through a pipe to a water wheel, causing the wheel to turn a shaft and produce useful work such as grinding flour.



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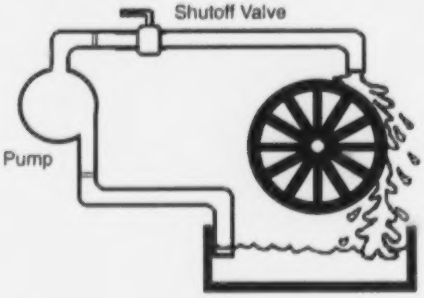
e. In the water circuit, the pump is the energy source, the wheel is the load, the pipes are the conductors, and the shut-off valve is the switch.



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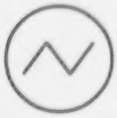
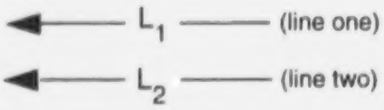
12. **Basic electrical symbols**

a. The symbol for an AC power source may be shown as:

(1)



(2)

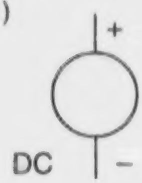


Note: The symbols presented here will help you work with simple circuit diagrams; symbols used with wiring diagrams and schematics will be treated in a later unit.

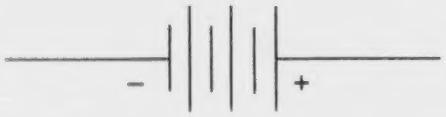
Information Sheet

b. The symbol for a DC power source may be shown as:

(1)

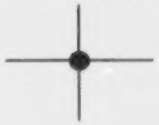


(2)

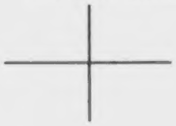


c. The symbol for electrical wires are straight lines and there are two methods for showing if lines are connected or not connected:

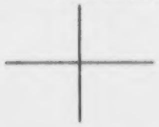
(1) Connected



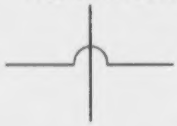
Not connected



(2) Connected



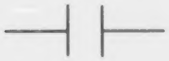
Not connected



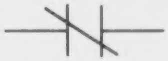
Note: When working with a wiring diagram or schematic, be sure you know what method the graphic uses to depict connected or not connected wires.

d. The symbol for switch contacts should indicate whether the contacts are normally open or normally closed:

(1) NO

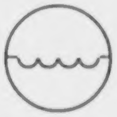


(2) NC



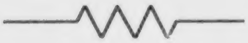
e. The symbol for a load may be a general symbol with a written designation or a specific symbol such as the one for a resistor or light.

(1) General load symbol:

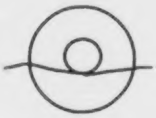


Information Sheet

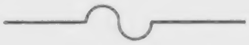
(2) Resistor:



(3) Light:

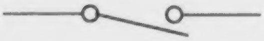


f. The symbol for a fuse is:

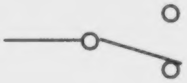


g. The symbols for switches show how switches work internally:

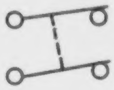
(1) Single Pole Single Throw (SPST)



(2) Single Pole Double Throw (SPDT)

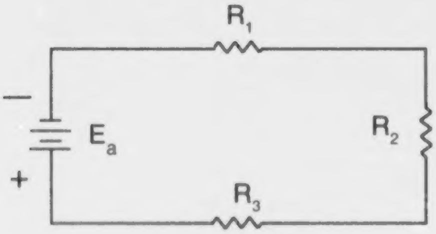


(3) Double Pole Double Throw (DPDT)



13. **The three types of circuits**

a. A series circuit is a circuit arranged so that all the current flowing in the circuit will pass through all loads in the circuit; current has only one path it can take.

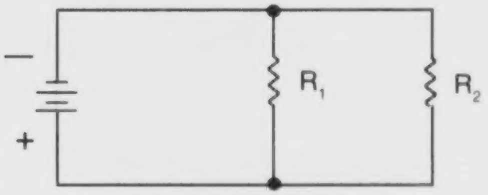


Series Circuit

Example: Inexpensive Christmas tree lights are arranged in a series circuit; when one light burns out, they all go out because the entire circuit is interrupted.

Information Sheet

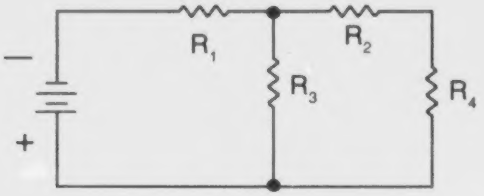
b. A parallel circuit is a circuit so arranged that all loads are connected to the same power source, but located side by side so that a division of current occurs; current has more than one path it can take.



Parallel Circuit

Example: More expensive Christmas tree lights are arranged in a parallel circuit; when one light burns out, the rest continue to burn because only one branch of the circuit is interrupted.

c. A series-parallel circuit is a circuit so arranged that some loads are connected in series and some loads are connected in parallel.



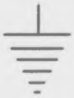
Series-Parallel Circuit

Note: Either parallel or series-parallel circuits are used in most common applications.

14. **Circuit grounding**

a. A ground in a circuit serves to protect users and technicians against hazardous electrical shock.

b. A ground should not be confused with neutral which may also be designated with the ground symbol.



c. All circuits should be grounded with a ground wire from the power source to a point on the equipment chassis.

d. In cases where a circuit cannot be grounded to the power source, the ground wire should be secured to a cold water pipe or to a grounding rod driven into the ground.

Information Sheet

e. Loose grounds create static in radio and television sets and contribute to heat build up in equipment.

f. Most electronic devices will not operate properly without proper grounding.

15. **Electrical measurements**

a. Being able to measure the electrical characteristics of a circuit is the basis of electrical troubleshooting.

b. Electrical measurements permit duplication of previous conditions.

c. Electrical measurements permit the comparison of present electrical conditions with a specified normal condition.

d. Electrical measurements are made with specialized instruments, and knowing how to use test instruments properly is a basic requirement for service technicians.

Note: Electrical test instruments and their uses are presented in detail in Unit 2 of this text.

e. In order to use the rules governing electricity, measurements must be expressed in basic units of amps, ohms, and volts, but very large or very small quantities are often expressed using mathematical prefixes from the metric system.

Metric Prefixes Above Zero

Notation	Pronunciation	Symbol	Amount
$1\ 000\ 000 = 10^6$	mega (meg-uh)	M	One million
$1\ 000 = 10^3$	kilo (kee-low)	k	One thousand
$100 = 10^2$	hecto (heck-tow)	h	One hundred
10 = 10	deka (deck-uh)	da	Ten

Metric Prefixes Below Zero

Notation	Pronunciation	Symbol	Amount
$0.1 = 10^{-1}$	deci (dess-uh)	d	One tenth
$0.01 = 10^{-2}$	centi (cent-uh)	c	One hundredth
$0.001 = 10^{-3}$	milli (mill-uh)	m	One thousandth
$0.000\ 001 = 10^{-6}$	micro (mike-row)	u	One millionth

f. Metric quantities must be converted to basic units before using them in formulas.

Examples: 10 kilowatts = 10,000 watts.
2 millivolts = .001 volts.
Also see Assignment Sheet 1

Information Sheet

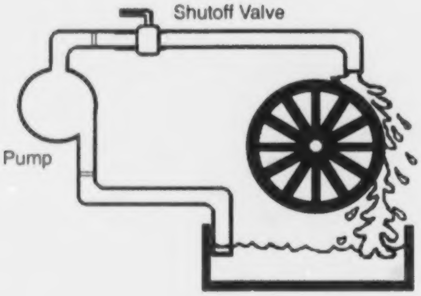
16. **Terms and abbreviations used in rules governing electricity**

a. E = EMF (electromotive force) or voltage measured in volts (V).

b. I = Intensity of current or amperage measured in amps (A) .

c. R = Resistance to current flow measured in ohms (Ω) or just resistance.

Example: When compared to a water circuit, electromotive force is similar to pressure created by the pump, current is similar to the rate of water flow, and resistance is similar to the way the water wheel slows water flow or the restriction caused by partially closing the water valve.



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17. **The three equations for using Ohm's Law**

a. Ohm's Law for electrical circuits expresses the mathematical relationship between voltage, current, and resistance in a circuit with resistive loads.

b. Ohm's Law may be expressed in three ways:

(1) The voltage required to force a given amount of current through a circuit is equal to the current times the resistance E = I x R.

(2) The current in a circuit is equal to the voltage divided by the resistance I = E / R.

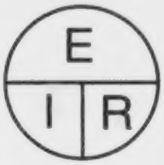
(3) The resistance of a circuit is equal to the voltage divided by the current R = E / I.

Note: See Student Supplement 1 for special information about applying Ohm's Law.

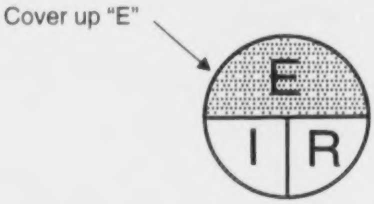
Information Sheet

18. Using Ohm's Law to find unknown values

a. Ohm's Law is often presented graphically as a triangle or a circle divided into three parts with each part representing one element of the law; the graphic presentation makes Ohm's Law easier to understand and use.

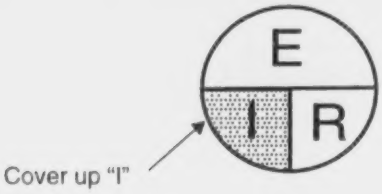


b. To determine an unknown voltage, cover the E, the unknown value, and since the I and R are side by side, multiply the I (A) times the R (Ω).



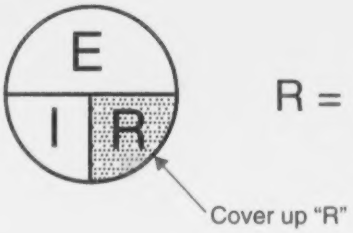
$$E = I \times R$$

c. To determine an unknown current, cover the I, the unknown value, and since E is over R, divide the E (V) by R Ω.



$$I = \frac{E}{R}$$

d. To determine an unknown resistance, cover the R (Ω), the unknown value, and since E is over I, divide E (V) by I (A).

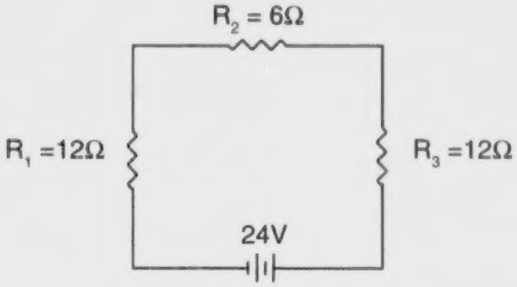


$$R = \frac{E}{I}$$

19. Using Ohm's Law to determine values in a series circuit

a. Resistances in series may be added to determine the total opposition to current flow.

Example: In this circuit, total opposition is 12 Ω + 6 Ω + 12 Ω = 30 Ω.



b. Current is the same at all points in a series circuit or I is constant in a series circuit.

Example: In the illustration in Step a, the current equals the total opposition divided by the voltage, so I = 24/30 = .8A measured at any point in the circuit.

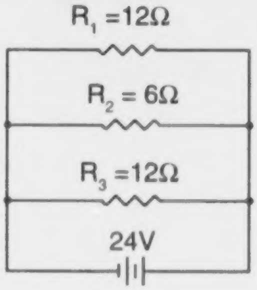
c. In series circuits there is voltage drop across each load, or, voltage is used in forcing current through each load; the total voltage drop must equal the total applied voltage.

Example: In the illustration in Step a, voltage drop across the 12 Ω load would be E = 12Ω x .8 A = 9.6V, across the 6Ω load would be E = 6Ω x .8A = 4.8V, and the second 12 Ω load also 9.6V, so 9.6V + 4.8V + 9.6V = 24V.

Note: The relationships presented in this objective demonstrate Kirchhoff's Law.

20. Using Ohm's Law to determine values in a parallel circuit

a. In parallel circuits, the voltage across each path is the same, but the current in each path is different.



b. To find the total current in a circuit, use Ohm's Law to find the current in each path, and then add the paths together.

Information Sheet

Example: In the illustration in Step a, $I_1 = 24V/12\ \Omega = 2A$, $I_2 = 24V/\ 6\Omega = 4A$, and $I_3 = 24V/12\Omega = 2A$; therefore, total current, $I_T = 2A + 4A + 2A = 8A$.

c. Total current may also be computed by using Ohm's Law with total resistance and total applied voltage.

d. Since total resistance is always less than any one resistance, computing total resistance of parallel loads requires use of the following formula: $1/R_T = 1/R_1 + 1/R_2 + 1/R_3$ etc.

In the illustration in Step a, $1/R_T = 1/12\Omega + 1/6\Omega + 1/12\Omega = 1/12\Omega + 2/12\Omega + 1/12\Omega = 4/12\Omega$; since $1/R_T = 4/12\Omega$, $1 \times 12\Omega = R_T \times 4$; therefore, dividing both sides of the equation by 4 gives us $R_T = 3\Omega$.

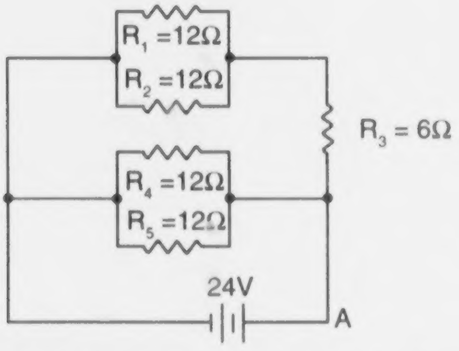
e. Where two resistances of the same value are connected parallel in a circuit, the total resistance of the two loads is equal to half of one of them.

Note: This is a commonly used short-cut method for applying the parallel resistances formula, but cannot be used for more than two loads or two loads of unequal resistance.

f. Voltage drop across each load is the same as the applied voltage, 24V.

21. **Using Ohm's Law to determine values in series-parallel circuits**

a. Combinations of series and parallel loads are handled by combining parallel resistances into a single resistance, and then adding resistances they are in series with.



b. To determine total resistance of a combination circuit, usually begin by combining resistances in the part of the circuit shown in the diagram farthest from the source.

Example: In the illustration in Step a, begin by combining R_1 and R_2 because they are farthest from the 24V source; R_1 and R_2 are of equal value and parallel, so their combined resistance is equal to one-half of either; $1/2 \times 12\Omega = 6\Omega$.

c. When a combined resistance is in series with another load, add the resistance of the other load to the combination.

Example: In the illustration in Step a, R_3 is in series with the combined value of R^1 and R^2; therefore, $6\Omega + 6\Omega = 12\Omega$.

d. Use the method described in b and c to continue combining the resistances until you reach the power source and determine a single total resistance.

Example: In the illustration in Step a, R_4 and R_5 are parallel and can be combined to equal 6Ω as with R_1 and R_2, and this combined value is in parallel with the combined value of R_1, R_2, and R_3. So the combined value to this point is determined by the formula $1/R_T = 1/12\Omega + 1/6\Omega = 1/12\Omega + 2/12\Omega = 3/12\Omega$. Since $1/R_T = 3/12\Omega$, $R_T \times 3 = 12\Omega \times 1$, and dividing both sides of the equation by 3 gives $R_T = 4\Omega$. This is the total combined resistance of the circuit.

e. Total current of a series-parallel circuit when measured at point A on the illustration would be calculated using Ohm's Law, $I = 24V/4\Omega = 6A$.

f. Voltage drop across loads in a series-parallel circuit varies from source voltage only in series parts of the circuit.

Example: In the illustration in Step a, the voltage drop across either R^4 or R^5 equals the source voltage, 24V; but the voltage drop across R_3 must be computed because it is in series with the combined value of R_1 and R_2. Since the total resistance of this branch of the circuit is 12Ω (as shown in c), the current draw at R_3 is $I = 24V/12\Omega = 2A$. Using this to compute the voltage drop across R_3 gives $E = 2A \times 6\Omega = 12V$.

22. **Applications of electronics in ACR control systems**

a. The increasing worldwide use of computer technology is evidenced in the increasing number of ACR control systems that make extensive use of solid-state electronic devices.

b. Advances in electronic technology have led to the production of smaller ACR control devices each year, and although smaller, the devices are capable of more functions.

c. Electronic thermostats and electronic fluid-control valves are popular applications in modern ACR control systems because they can fit in smaller spaces and still perform more functions than previous models.

d. Because electronic activity inside semiconductors cannot be observed, their increasing use in electronic devices makes it extremely important for modern ACR service technicians to know electrical theory and how to effectively use test instruments.

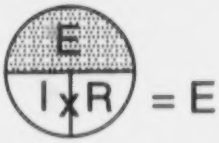
Fundamentals of Electricity
Unit 1

Student Supplement 1—Applying Ohm's Law

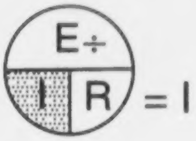
Mnemonics (knee-mon-iks) are devices such as short songs or poems used to make it easier to remember things. The following short poem is a mnemonic designed to help you when you don't have a book handy and need to apply Ohm's Law on the job.

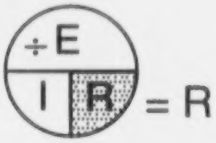
Hide and Seek With Ohm's Law

When I and R are side by side,
And E is hid from you,
The I times R will give you E,
Although E's hid from view.



When unknown I or R you seek,
Hide one, leave one to show,
Then E divided by what's left,
Is what you want to know.





Fundamentals of Electricity
Unit 1

Assignment Sheet 1—Convert Electrical Measurements to Basic Units

Name______________________________Overall Rating__________

Evaluation Criteria	**Rating**
Number of answers attempted	_____
Number of correct answers	_____

Directions: Express the following measurements in basic units of amps, ohms, and volts; refer to the charts in Objective 15 as needed.

Example: 100 milliamps ____________
Answer: 100A

Example: 100 volts __________
Answer: 100V

Hint: If a measurement is already expressed in basic units, no change is required.

A. 1.5 microamps ____________________________

B. 1,010 kilowatts ____________________________

C. 30 millivolts ____________________________

D. 3 megohms ____________________________

E. 10 amps ____________________________

Fundamentals of Electricity
Unit 1

Assignment Sheet 2—Use Ohm's Law to Determine Unknown Values in Resistive Circuits

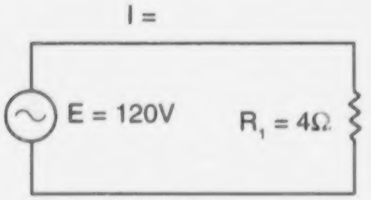
Name____ Overall Rating__________

Evaluation Criteria	**Rating**
Number of answers attempted	_____
Number of correct answers	_____

Directions: Reference as needed the procedures in Objectives 18, 19, 20, and 21, draw a circle depicting Ohm's Law, and find the unknown values in the following circuits. Round answers to two decimal places.

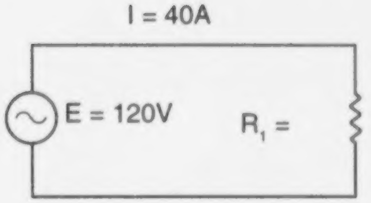
A. Sketch a graphic representation of Ohm's Law below this line.

B.



Current = __________

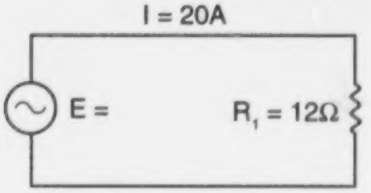
C.



Resistance = _______

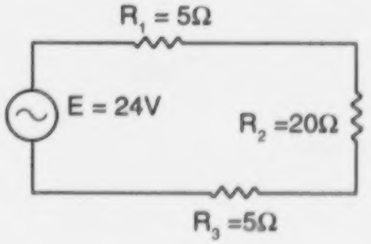
Assignment Sheet 2

D.


I = 20A
E =
$R_1 = 12\Omega$

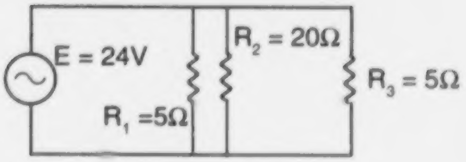
Electromotive force = ______

E.


$R_1 = 5\Omega$
E = 24V
$R_2 = 20\Omega$
$R_3 = 5\Omega$

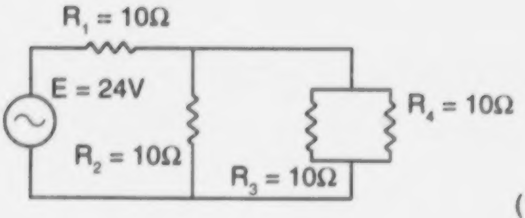
(1) R_T = ______
(2) I = ______
(3) Voltage drop at R_2 = ______

F.


E = 24V
$R_1 = 5\Omega$
$R_2 = 20\Omega$
$R_3 = 5\Omega$

(1) R_T = ______
(2) I_T = ______
(3) Voltage drop at R_2 = ______

G.


$R_1 = 10\Omega$
E = 24V
$R_2 = 10\Omega$
$R_3 = 10\Omega$
$R_4 = 10\Omega$

(1) R_T = ______
(2) I_T = ______
(3) Voltage drop at R_1 = ______
(4) Voltage drop at R_2 = ______

Tools, Materials, and Test Instruments

Unit 2

Objective Sheet

Unit Objective

After completing this unit, the student should be able to use digital and analog voltmeters to check power sources and use an ohmmeter to check continuity of fuses and resistance of resistors. The student should also be able to use an ohmmeter to identify electrical conditions of a hermetic compressor and use an ammeter to read start and run amperage of a motor. The student should demonstrate these competencies by completing the assignment and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to tools, materials, and test instruments with their correct definitions.
2. Complete statements about tools.
3. Solve problems about electrical wiring.
4. Complete statements about connecting electrical wires.
5. Select true statements about guidelines for splicing wires.
6. Complete statements about connecting wires to terminals.
7. Select true statements about test instrument characteristics.
8. Solve problems about reading test instruments.
9. Complete statements about using voltmeters and voltage testers.
10. Solve problems about using ohmmeters.
11. Select true statements about using ohmmeters to check motors.

Objective Sheet

12. Complete statements about checking a hermetic motor with an ohmmeter.
13. Complete statements about using ammeters.
14. Solve problems about useful test accessories.
15. Select true statements about the effects of current on the human body.
16. Complete statements about how to avoid electrical accidents.
17. Complete statements about rescue procedures for electrical accidents.
18. Read a voltmeter. (Assignment Sheet 1)
19. Read an ammeter. (Assignment Sheet 2)
20. Read an ohmmeter. (Assignment Sheet 3)
21. Identify start, run, and common terminals and draw the windings of a split-phase motor. (Assignment Sheet 4)
22. Solder terminals onto wires. (Job Sheet 1)
23. Splice wires using wire nuts. (Job Sheet 2)
24. Use digital and analog voltmeters to check power sources. (Job Sheet 3)
25. Use an ohmmeter to check continuity of fuses. (Job Sheet 4)
26. Use an ohmmeter to determine the resistance of resistors. (Job Sheet 5)
27. Use an ohmmeter to identify terminals and electrical condition of a hermetic compressor. (Job Sheet 6)
28. Use an ammeter to read start and run amperage of a motor. (Job Sheet 7)

Tools, Materials, and Test Instruments
Unit 2

Information Sheet

1. **Terms and Definitions**

   a. **AWG (American Wire Gauge)**—A classification system for identifying wire conductors by diameter and number

   b. **Ground**—A component or circuit electrical problem in which some part of the circuit comes in contact with the chassis or some other component

   c. **NEC (National Electric Code)**—Guidelines dedicated to the protection of life and property in the uses and functions of electrical materials in residential and commercial applications

   d. **Short**—An electrical problem in which current is diverted from its intended path into a path of lower resistance and which often blows a fuse or trips a breaker

   e. **Open**—An electrical problem in which the path of a circuit has been interrupted

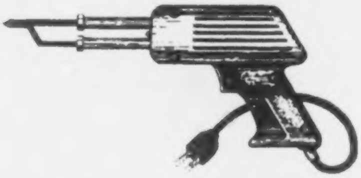
2. **Tools**

   a. Wire strippers/crimpers come in a variety of types and are used to cut electrical wires, to strip insulation from around wires, and to crimp terminals onto wires.

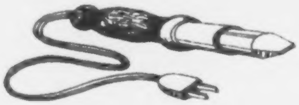
   b. Lineman's pliers are used for a variety of jobs such as cutting wires, driving and pulling staples or nails, gripping objects, and stripping wires.

Information Sheet

c. Soldering tools of different sizes and ratings are used to solder wires together or to solder terminals to the ends of wires.



Soldering gun



Soldering iron

d. A variety of hand tools such as assorted sizes and types of screwdrivers, pliers, and hammers are useful in working with electrical components.

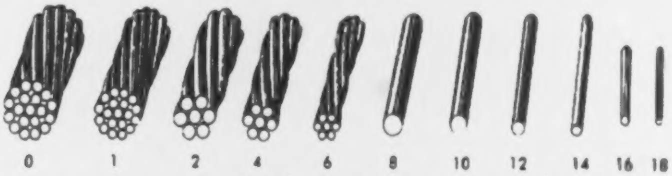
e. Tools of any kind used in electrical work must have insulated handles to prevent electrical shock when working with "live" circuits or when a "dead" circuit turns out to be "live."

Information Sheet

3. Electrical wiring

   a. Equipment wiring is selected according to an AWG number to identify wire diameter and letters to indicate the insulation type.

   b. AWG wire sizes decrease in number as the wires increase in diameter; in other words, the smaller the number the larger the wire.



   c. Insulation on wires around major equipment is usually R for rubber or T for thermoplastic, H to indicate acceptability for higher load ranges, and W to indicate suitability for wet locations.

   Examples: RHW indicates a moisture and heat resistant rubber covering for dry and wet locations where temperatures do not exceed 167°F. THW indicates a moisture and heat resistant thermoplastic for dry and wet locations where temperatures do not exceed 194°F.

   d. When reading wire sizes, the first number is the AWG diameter, and the second number indicates how many conductors are in the wire.

   Example: 10/3 indicates a 10-gauge wire with three conductors.

   e. The maximum amperage a wire can safely carry is known as ampacity, and the ampacity increases as the wire number decreases.

AWG#	Ampacity
14	15
12	20
10	30
8	45
6	65
4	85
2	115
1	130
0	150
00	175
000	200

Information Sheet

f. Low ampacity wires used in high ampacity applications can malfunction and create a fire hazard, so never replace an AWG wire with a smaller wire!

Example: The wiring for an electric furnace has a #8 AWG wire for ground and #6 AWG wires for both hot leads; if you used a #10 AWG wire for any of these applications, there is a potential for overheating, and that is why the National Electric Code forbids such an application.

4. Connecting electrical wires

a. Wires must be properly connected to each other and to components to prevent overheating or voltage drops because a loose connection increases resistance.

b. Electrical wires are connected to components or other wires in a variety of ways such as:

(1) screw terminals.
(2) crimp-on terminals.
(3) splices and soldered splices.
(4) wire nuts.
(5) terminal blocks.

c. Wire splices or other soldered electrical connections are often made with rosin-core 60/40 solder which is an alloy of 60% tin and 40% lead and has rosin flux inside the solder.

Note: See Job Sheet 1.

d. Most connections must be insulated with insulation sleeves, insulating tape, or some other insulating product.

e. Tape used for insulating conductors includes plastic, rubber, glass cloth, and other materials rated for a variety of factors including:

(1) stretch characteristics.
(2) humidity and temperature resistance.
(3) ultraviolet ray resistance.
(4) corrosive and other wear conditions.

Caution: Because it may fail to protect and cause other problems, a cheap electrical tape could actually cost more in the long run; for better grades of tape it takes less to provide quality insulation and the better grades last longer.

Information Sheet

5. **Guidelines for splicing wires**

   a. Before wires can be properly spliced, insulation must be stripped from the conducting wire.

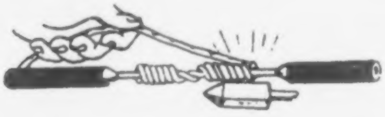
   b. While wire stripping is simple, it takes practice to learn to strip insulation away without damaging the wire.

      Note: See Job Sheet 1.

   c. Wires may be spliced together using a variety of twisting techniques.

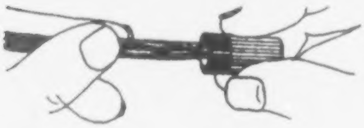
      Note: See Student Supplement 1.

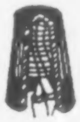
   d. After splicing, solder can be added to give the splice more strength and less resistance.



   e. Screw-on wire nuts work well on splices if used properly, and they require no added tape or other insulation because they are made of insulating material.

      Note: See Job Sheet 2.





   f. Wire nuts and some other solderless connectors are often color coded to identify the gauge of wire they are designed to be used with.

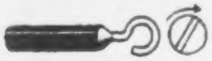
      Example: Orange wire nuts are usually designed to connect one #14 with one to three #18 or one #14 with one #16, or two to four #16.

   g. Before applying wire nuts, wire splices can be soldered to add strength and reduce resistance.

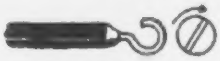
Information Sheet

6. Connecting wires to terminals

a. To attach bare wire to a screw terminal, loop the wire around the screw in the direction the screw turns to avoid having the wire slip out from under the screw when you tighten the screw.



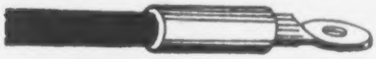
Right



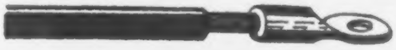
Wrong

b. When greater stability is desired, crimp or solder a terminal

Note: See Job Sheet 1.



Right



Wrong

c. Use a similar technique to crimp or solder a spade or push-on terminal onto the end of a wire.

d. Terminal kits are available with a wide variety of solder or solderless terminals for use in making electrical connections.

7. Test instrument characteristics

a. Selection of a test instrument depends upon the type of work you are doing, the type of equipment you are checking, and what you want to find out about the equipment.

b. Basic test instruments include meters for checking voltage, meters for checking amperage, and other meters for checking resistance.

c. There are specialized test instruments for checking capacitors, hermetic motors, power consumption or watts, and other functions.

d. A test instrument may contain only one meter and perform only one function, or contain several meters in a single case and perform several functions.

8. Reading test instruments

a. Meters are either analog, using a needle or similar means in front of a scale to indicate readings, or digital, using an LED display to indicate readings.

b. Analog meters may have selected scales displayed on the same surface, so take care to select a scale that matches what you are measuring.

Information Sheet

c. Analog meters should be read in the center two thirds of the scale for greatest accuracy.

d. Count the number of graduations between the major divisions on the scale to determine what each graduation represents.

e. If a needle points between graduations, interpolate between the lines to determine the reading.

f. Digital meters are either autoranging and change scales for you, or have buttons or switches which must be changed to select a scale to match what you are measuring.

g. Most analog meters have an adjusting screw or knob to adjust the needle to zero before using.

h. If an ohmmeter or any digital meter will not zero or gives erratic readings, it probably needs a new battery.

9. Using voltmeters and voltage testers

a. Voltmeters and voltage testers indicate if voltage is present, and if so, how much and where.

b. Knowing if voltage is present or not can be an important safety factor as well as useful in diagnosing problems.

c. Knowing how much voltage is present is important because a motor or other load will usually not work properly if voltage available is less than 10 percent below its rating and will often "burn up" if voltage in excess of 10 percent above its rating is applied.

d. Identifying where voltage is present in a circuit is also important because this can be used to identify which components are open or where the circuit is broken.

e. Voltmeters give a reading when the two probes are placed on the wiring of a circuit so as to complete a path through the meter.

f. Other voltage testers use lights to indicate the presence of voltage, or even different lights, or a change in the intensity of the lights to indicate levels of voltage.

g. Some voltage testers will have two probes like a meter; others will have a single probe, and some do not actually have to come in contact with the conductors, but read "through the insulation."

Information Sheet

10. Using ohmmeters

a. Ohmmeters read resistance, and resistance readings can be interpreted to indicate:

(1) continuity.
(2) opens.
(3) shorts.
(4) grounds.

b. An ohmmeter uses its own power source, usually a DC battery, to send current through a component or the portion of a component between the points where the ohmmeter probes are applied.

c. By measuring the current flow through the component or portion of a component, the resistance to flow is determined and displayed by the meter.

d. Continuity is indicated by a resistance reading from zero to very high, and should match the specified resistance of the component.

e. An open is indicated by a very high resistance reading, either a very large number such as 10 megohms or a number too large to measure, represented by the symbol for infinity ∞.

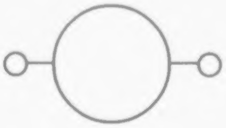
f. A short is indicated by a resistance reading different from the resistance specified for the component, a resistance reading inconsistent with standard component wiring, or continuity where there should be none.

g. A ground is indicated by continuity between the wiring or the normal path and ground, such as the shell of a motor, refrigerant tubing, or the equipment chassis.

11. Using an ohmmeter to check motors

a. When the condition of a motor is unknown or when the wiring diagram is missing, ohmmeter checks will indicate valuable service information about the motor.

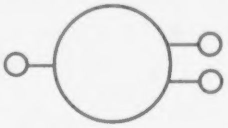
b. A motor which has a single winding with two leads or terminals can only be checked for an open or a ground.



Information Sheet

c. A multispeed motor can also be checked for an open or ground, but on a multispeed motor or any motor with more than one winding, the windings themselves can be identified by resistance readings.

Note: This will be covered in depth in the units about motors.



d. The most common application of ohmmeters in checking motors is in checking hermetic compressor motors.

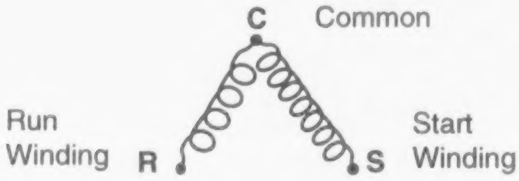
Note: See Assignment Sheet 4 and Job Sheet 5.

12. **Checking a hermetic compressor motor with an ohmmeter**

a. Most single-phase hermetic compressor motors have two windings, start and run, and the start winding has a greater resistance than the run winding.

b. In a single-phase hermetic compressor, one end of each winding is connected to the same terminal, called a common terminal because both windings have this terminal in common.

c. The other ends of the windings are connected to a start terminal and a run terminal respectively.



d. To test a single-phase hermetic compressor motor with an ohmmeter, use the following procedure:

(1) Place ohmmeter probes at C and S to read the start winding resistance.
(2) Place probes at C and R to read the run winding resistance.
(3) Place probes at S and R to read the combined resistance of both windings.
(4) If the reading from C to S plus the reading from C to R equals the reading from S to R the motor is operational.

Information Sheet

(5) If two of the resistance readings combined do not come very close to equalling the third resistance reading, it indicates a short.

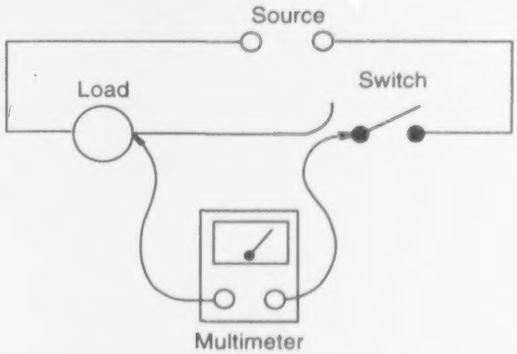
(6) Continuity between any of the terminals and the shell of the compressor indicates a grounded compressor.

Note: Most compressor manufacturers consider a compressor motor grounded if this resistance reading is 100,000 ohms or less. This procedure for checking a hermetic compressor is dealt with in Job Sheet 5.

13. Using ammeters

a. There are two types of ammeters, in-line and clamp-on.

b. In-line ammeters are often found in VOMs and multimeters, and must be connected in series with the load.



c. In-line ammeters will usually read current from milliamps to a maximum of 10 amps.

d. Clamp-on ammeters do not actually connect to the circuit in any way, but are clamped around one of the conductors in the circuit, and read current by measuring the magnetic field around the wire.

Information Sheet

e. Clamp-on ammeters come with scales ranging from 0-6 amps up to scales that will read several hundred amps.

f. Be sure to clamp the jaws of the meter around only one conductor in order to get a proper reading.

g. To make reading low amperage easier, wrap a single conductor through the ammeter jaws several times to magnify the reading, then divide the meter reading by the number of times the conductor passes through the jaws to find the correct resistance.

h. Many service technicians carry a "10-wrap" coil to check very low amperage readings because the reading can be converted by simply moving the decimal one place to the left to divide by ten.

Example: If the reading with a 10-wrap coil is 3.0 amps, the resistance would actually be .3 amps.

Information Sheet

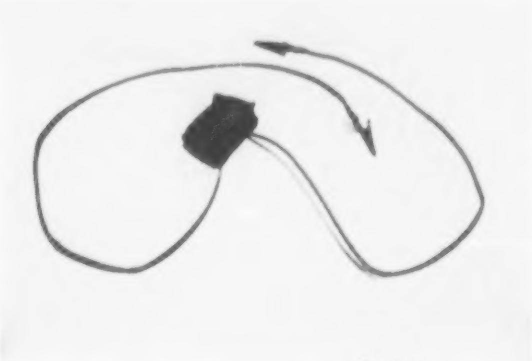
14. Useful test accessories

a. Most service technicians carry several different test cords, jumper wires, and adapters to make testing easier.

b. Cords with a male plug or a female plug on one end and alligator clips on the other end are used to apply power directly to a load.

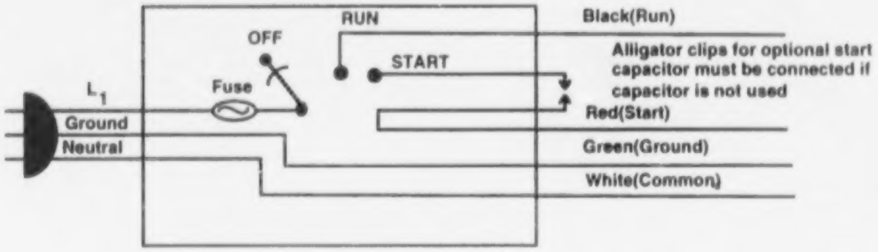
c. Jumper wires with alligator clips on both ends are used to bypass a control or broken path.

d. A switch hooked to wires with alligator clips on the other end is used to add a temporary control.



Information Sheet

e. Cords, jumper wires, and other adapters can be combined with test instruments and each other in the field, and some prepackaged kits perform many different tests.


RUN
OFF
START
Fuse
L_1
Ground
Neutral
Black(Run)
Alligator clips for optional start capacitor must be connected if capacitor is not used
Red(Start)
Green(Ground)
White(Common)

15. **Effects of current on the human body**

a. Never underestimate the potential danger of electricity.

b Current as low as 50 milliamps (50 thousandths of an ampere) can cause heart convulsions and death.

c. Even a 24V circuit will carry a current of .1A to .2A, which is 100 to 200 milliamps, enough current to cause serious injury or death if it passes through your heart.

d. The potential for much more current and increased danger is present with higher voltages.

e. Higher voltages and currents also present a danger of creating a situation called arcing, where an electrical arc literally jumps a gap and goes through your body to ground.

Information Sheet

16. How to avoid electrical accidents

a. Pay attention because most electricial accidents happen through carelessness or misuse.

b. Remember that the involuntary reaction to electrical shock can cause you to injure yourself or others.

Example: A service technician jerks and arm back quickly as a reflex reaction to unexpected electrical shock, and jabs an elbow into a turning fan blade.

c. Work on live circuits only when absolutely necessary.

d. Stand on dry, nonconductive surfaces, or wear shoes with dry, nonconductive soles when working with live circuits.

e. Work with a coworker whenever possible when working with live circuits.

f. Use one hand only when working with live circuits.

Note: Experienced technicians often put one hand behind their back when using test instruments on operating equipment.

g. Assume all circuits are live unless you have personally checked for voltage immediately prior to working on the circuit.

h. Use tag and lock procedure to insure that circuits will not be reenergized while service is underway.

Note: Tag and lock means to fasten breakers or disconnects in the off position, and place a visible tag on it explaining that service is being performed.

17. Rescue procedure for electrical accidents

a. Turn off the power to the circuit or equipment involved in an electrical accident as quickly as possible if you can locate where to turn it off.

b. Do not come in contact with a person being shocked or with anything around that might conduct electricity.

Caution: You will not be of any assistance to the person being shocked if you become part of the problem.

c. Decide if it would be easier to move a person being shocked, or easier to move the conductor the person is in contact with.

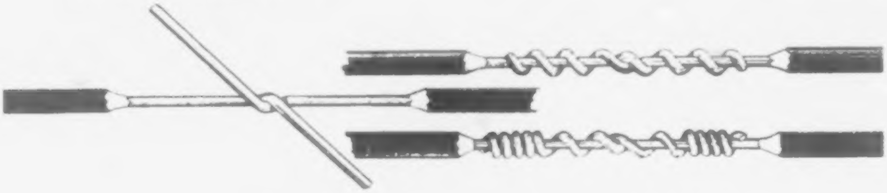
d. Use a dry, nonconductive object such as a board, rubber mat, or several thicknesses of paper or cloth to separate the person and the conductor.

e. Notify emergency personnel as soon as possible.

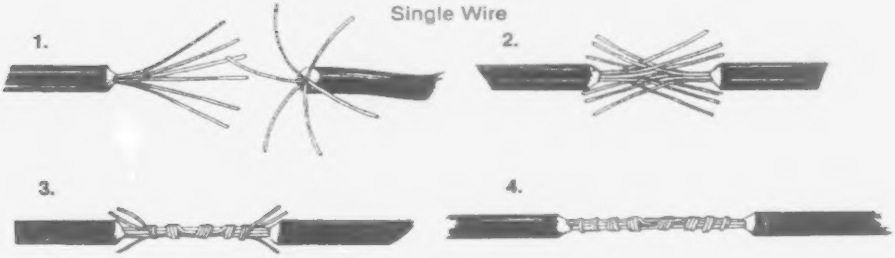
Tools, Materials, and Test Instruments
Unit 2

Student Supplement 1—Techniques for Splicing

a. Make a simple splice by twisting two conductors together so that they form one continuous wire.

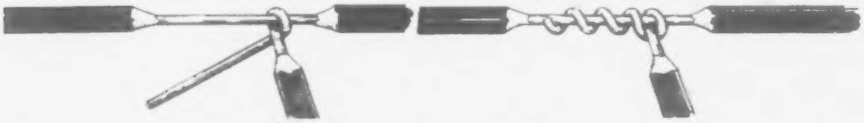


Simple splice with single wire

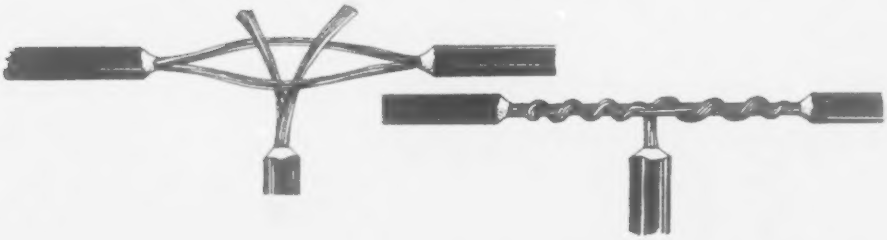


Simple splice with stranded wire

b. Make a simple tap by twisting a second wire onto a source wire in such a way that it taps into the source wire at an angle.



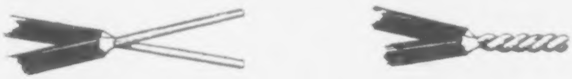
Simple tap with single wire



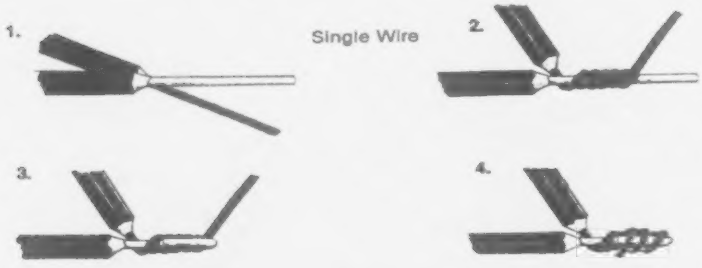
Simple tap with stranded wire

Student Supplement 1

c. Make pigtail splices by twisting one conductor around another at an end point.

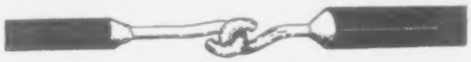


Pigtail on single wires



Pigtail on stranded to single wire

d. Make a hook splice where single or stranded wires are too short to twist for a simple splice or where thicker wires would be difficult to twist.



Hook splice

e. Cover all splices with quality electrical tape to protect from electrical shorts and to protect technicians from electrical shock when equipment is serviced.

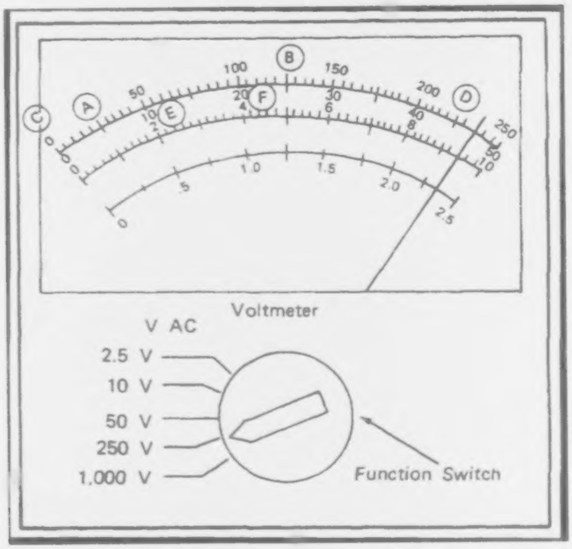
Tools, Materials, and Test Instruments
Unit 2

Assignment Sheet 1—Read a Voltmeter

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Number of answers attempted	______
Number of correct answer	______

Directions: Study the voltmeter in the following illustration. Make readings at points A,B,C,D,E, and F. Remember to use the scale indicated in the written problem below the illustration, and also remember to read from left to right on the scale.



A
B
C
D
E
F
0
50
100
150
200
250
10
20
30
40
50
2
4
6
8
10
.5
1.0
1.5
2.0
2.5
Voltmeter
V AC
2.5 V
10 V
50 V
250 V
1,000 V
Function Switch

Example: With the function switch at 250V, the meter needle is pointing to 235V.

a. Function switch is at 250V; needle points to B on scale.

Answer ____

b. Function switch is at 50V; needle points to B on scale.

Answer ____

Assignment Sheet 1

c. Function switch is at 1000V; needle points to E on scale.

Hint: Use the 0-10, 10 = 1,000, scale in the 1000V position.

Answer____

d. Function switch is at 250V; needle points to A on scale.

Answer____

e. Function switch is at 250V; needle points to C on scale.

Answer____

f. Function switch is at 1000V; needle points to F on scale.

Answer____

g. Function switch is at 50V; needle points to F on scale.

Answer____

h. Function switch is at 250V; needle points to D on scale.

Answer____

i. Function switch is at 250V; needle points to F on scale.

Answer____

j. Function switch is at 50V; needle points to D on scale.

Answer____

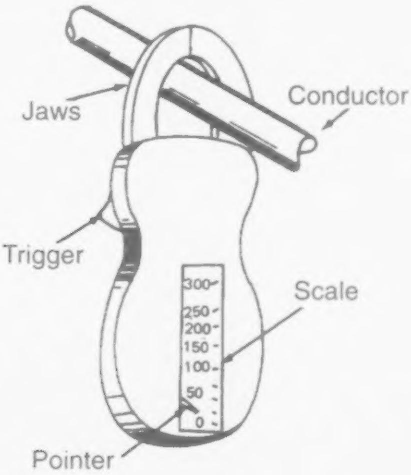
Tools, Materials, and Test Instruments
Unit 2

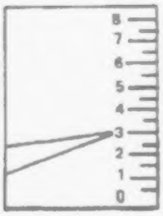
Assignment Sheet 2—Read an Ammeter

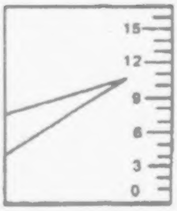
Name____ Overall Rating_______

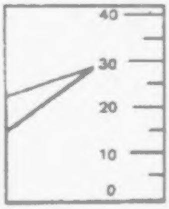
Evaluation Criteria	**Rating**
Number of answers attempted	______
Number of correct answers	______

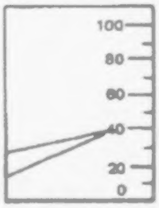
Directions: Study the ammeter in the following illustration. Note that the ammeter has a rotary scale with five different amperage ratings on it. In the space below each scale illustration, write in the correct amperage reading.

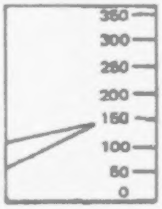

Jaws
Conductor
Trigger
Scale
Pointer
300
250
200
150
100
50
0








100
80
60
40
20
0


350
300
250
200
150
100
50
0

a.__________ b.__________ c.__________ d.__________ e.__________

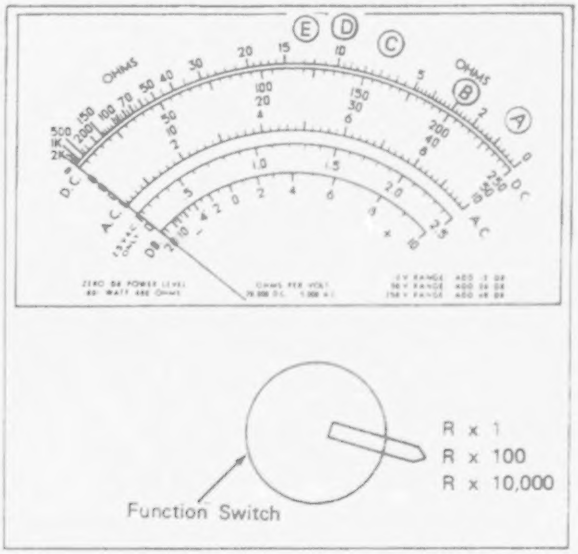
Tools, Materials, and Test Instruments
Unit 2

Assignment Sheet 3—Read an Ohmmeter

Name____________________ Overall Rating________

Evaluation Criteria	**Rating**
Number of answers attempted	____
Number of correct answers	____

Directions: Study the ohmmeter in the following illustration. Be sure to read the ohmmeter scale from right to left and write in the answers to the written problems below the illustration.



Example: With the function switch at R x 10,000 and the needle pointing to 2 on the scale, the reading is 20,000 ohms or 20,000Ω, when expressed with the ohms symbol. To arrive at the answer, multiply 10,000 x 2 = 20,000Ω.

a. Function switch is at R x 1; needle points to B on scale.

Answer ____________________

b. Function switch is at R x 10,000; needle points to E on scale.

Answer ____________________

Assignment Sheet 3

c. Function switch is at R x 100; needle points to C on scale.

Answer____

d. Function switch is at R x 10,000; needle points to A on scale.

Answer____

e. Function switch is at R x 1; needle points to E on scale.

Answer____

f. Function switch is at R x 100; needle points to B on scale.

Answer____

g. Function switch is at R x 1; needle points to A on scale.

Answer____

h. Function switch is at R x 1; needle points to D on scale.

Answer____

i. Function switch is at R x 100; needle points to E on scale.

Answer____

j. Function switch is at R x 10,000; needle points to C on scale.

Answer____

Tools, Materials, and Test Instruments
Unit 2

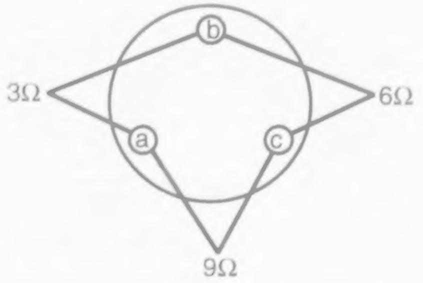
Assignment Sheet 4—Identify Start, Run, and Common Terminals and Draw the Windings of a Split-Phase Motor

Name____ Overall Rating________

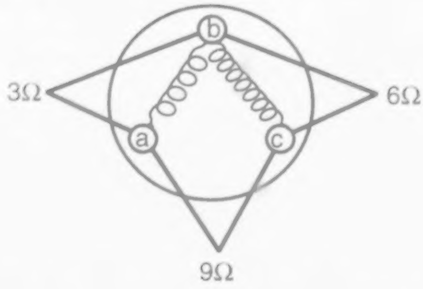
Evaluation Criteria	**Rating**
Number of terminals properly identified	______
Number of windings properly drawn	______

Review: In the following diagrams, the resistance readings are shown for the terminals which the ohmmeter probes are touching. The terminal which is not being touched when the highest reading is obtained, must be the common terminal. Once the common terminal is identified, windings can be properly drawn. The winding with the higher resistance is the start winding; therefore, it is connected to the start terminal. The winding with the lower resistance is the run winding and is connected to the run terminal.

Example: In the following diagram, 9 Ω is the highest reading, since B is not being touched when this reading is obtained, B is the common terminal.

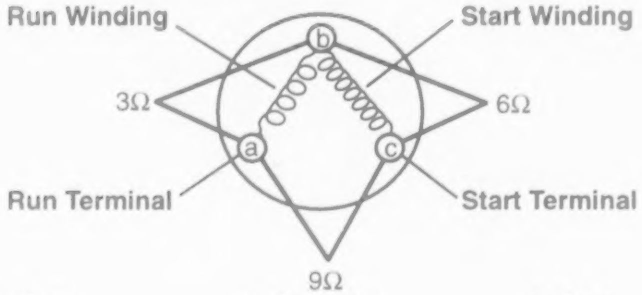


The windings can then be drawn between B and A, and also between B and C.



Assignment Sheet 4

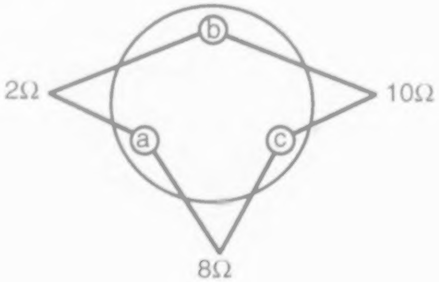
Since B to C has more resistance than B to A, B to C is the start winding, and C is the start terminal. This leaves B to A as the run winding and A as the run terminal.


Run Winding
Start Winding
b
3Ω
6Ω
a
c
Run Terminal
Start Terminal
9Ω

a. Run b. Common c. Start

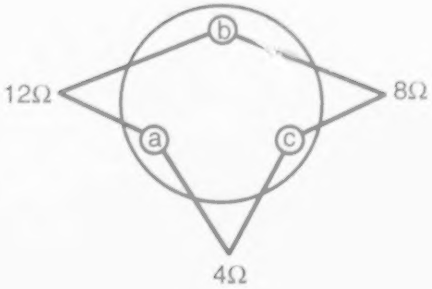
Directions: Use the procedure described in the review and example to identify the terminals and draw the windings for the following diagrams.

Problem A


b
2Ω
10Ω
a
c
8Ω

a. ______________ b. ______________ c. ______________

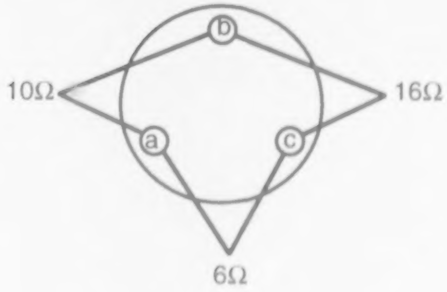
Problem B


b
12Ω
8Ω
a
c
4Ω

a. ______________ b. ______________ c. ______________

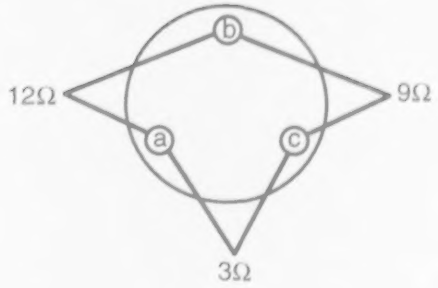
Assignment Sheet 4

Problem C


b
10Ω
16Ω
a
c
6Ω

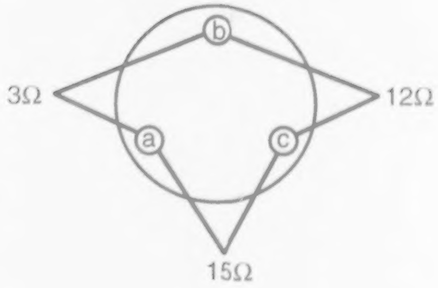
a. ______________ b. ______________ c. ______________

Problem D


b
12Ω
9Ω
a
c
3Ω

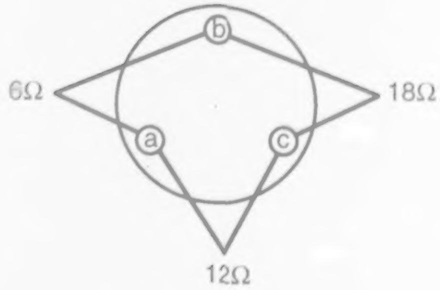
a. ______________ b. ______________ c. ______________

Problem E


b
3Ω
12Ω
a
c
15Ω

a. ______________ b. ______________ c. ______________

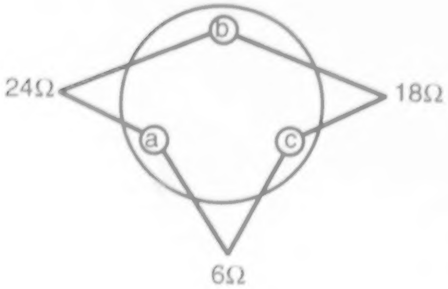
Problem F


b
6Ω
18Ω
a
c
12Ω

a. ______________ b. ______________ c. ______________

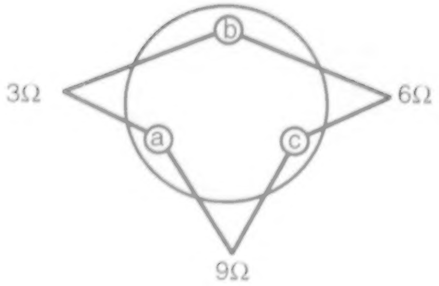
Assignment Sheet 4

Problem G


b
24Ω
18Ω
a
c
6Ω

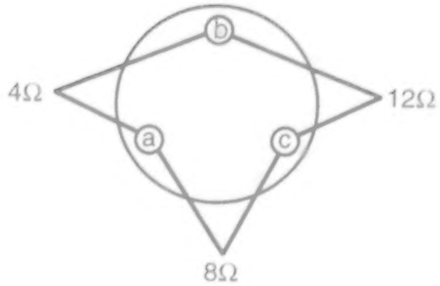
a. ______________ b. ______________ c. ______________

Problem H



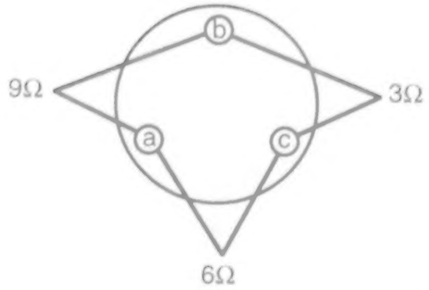
a. ______________ b. ______________ c. ______________

Problem I


b
4Ω
12Ω
a
c
8Ω

a. ______________ b. ______________ c. ______________

Problem J



a. ______________ b. ______________ c. ______________

Tools, Materials, and Test Instruments
Unit 2

Job Sheet 1—Solder Terminals Onto Wires

Name____ Attempt Number________

Date____ Overall Rating________

Evaluation Criteria	**Rating**
Wire properly stripped	_____
Terminal crimped properly onto wire	_____
Terminal connection properly soldered	_____

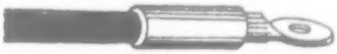
A. Tools and materials

Soldering gun or iron
Rosin-core solder
Terminals as selected by instructor
Wire as selected by instructor
Wire strippers/crimpers
Safety glasses

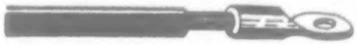
B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Measure how much wire will fit inside the sleeve of the terminal you are using.



Right

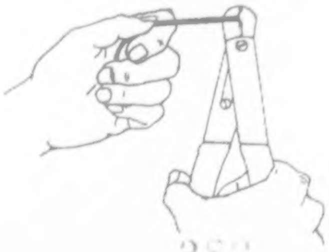


Wrong

Note: Do not strip more insulation than is necessary because this could leave a gap between the terminal and the insulation.

☐ 3. Place the wire in the proper slot in the wire stripper and align it with the mark on the wire.

☐ 4. Squeeze the stripper and work it back and forth until you make a cut around the entire insulation.



Job Sheet 1

☐ 5. Hold the wire tight with one hand and use the stripper or a pair of pliers to gently move the insulation back and forth until you can pull it off.

☐ 6. If the wire is a stranded wire, heat the bare wire with a soldering tool and apply solder until it fills all strands.

Note: This process of applying a coating of solder is referred to as "tinning."

☐ 7. Slide a wire terminal onto the bare end of the wire.

Note: Some terminals will have an extra length of sleeve or metal designed to wrap around the insulation to provide added strength.

☐ 8. Crimp terminal onto wire and insulation as necessary.

☐ 9. Heat the part of the terminal on the bare wire with the soldering tool.

☐ 10. Apply solder until it flows through the connection.

☐ 11. Remove soldering tool.

☐ 12. Have your instructor inspect your work.

☐ 13. Repeat the procedure for other types of terminals selected by your instructor.

Note: A procedure similar to the one just outlined can also be used for soldering wire splices.

☐ 14. Allow soldering tool to cool and return tools and materials to proper storage.

Comments ______________________________

____

____

____

Tools, Materials, and Test Instruments
Unit 2

Job Sheet 2—Splice Wires Using Wire Nuts

Name ______________________ Attempt Number _______

Date ______________________ Overall Rating _______

Evaluation Criteria	**Rating**
All wires properly prepared for splicing	_____
Wire nuts properly applied and secured	_____
Variety of wire sizes and wire nuts used	_____

A. Tools and materials

Assorted pieces of electrical wire of different gauges
Assorted sizes of wire nuts
Safety glasses
Wire strippers

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Select two or three pieces of electrical wire to splice.

☐ 3. Consult a chart or the specifications on the wire nut container to select the proper size wire nut to match the wires selected.

☐ 4. Strip the insulation from the end of each wire a distance of about three-fourths the length of the wire nut selected.

☐ 5. Align the ends of the wires with each other and twist them loosely together.

Note: Do not twist the wires tightly together; allow the wire nut to do the twisting, that is what they are made for.

☐ 6. Hold the wires firmly and place the wire nut over the ends of the wires with the other hand.

☐ 7. Twist the wire nut in a clockwise direction so that it screws tightly onto the wires.

☐ 8. Hold the wire nut in one hand and pull hard on each of the wires to make sure they do not pull out of the wire nut.

Job Sheet 2

☐ 9. If any of the wires pull out of the wire nut, take the wire nut off and repeat the procedure until wires are securely held together by the wire nut.

☐ 10. Repeat the procedure with various combinations of wires and wire nuts as directed by your instructor.

Example: Orange wire nuts can be used to connect one #14 with one to three #18 or one #14 with one #16, or two to four #16.

☐ 11. Have your instructor check your wire nut splices.

☐ 12. Return tools and materials to proper storage.

Comments ____

Tools, Materials, and Test Instruments
Unit 2

Job Sheet 3—Use Digital and Analog Voltmeters to Check Power Sources

Name______________________________ Attempt Number_______

Date______________________________ Overall Rating_______

Evaluation Criteria	**Rating**
120V & 240V outlet checks completed/analog	_____
120V & 240V outlet checks completed/digital	_____
240V one-phase disconnect checks completed/analog	_____
240V three-phase disconnect checks completed/digital	_____

A. Tools and materials

Digital and analog voltmeters
120V wall outlet
240V wall outlet
240V one-phase disconnect
Three-phase disconnect
Pencil or pen to complete entries
Safety glasses

B. Procedure

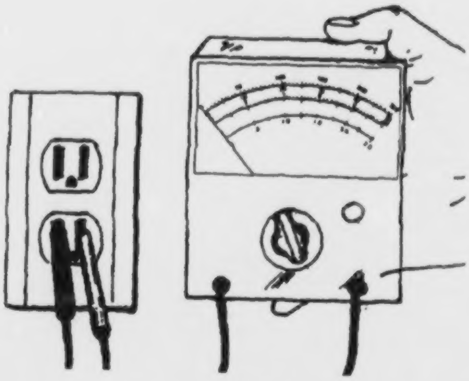
☐ 1. Put on safety glasses.

☐ 2. Select highest AC voltage scale.

☐ 3. Place voltmeter probes so that you can check across a 120V wall outlet.

☐ 4. Record your findings:

digital __________ analog __________



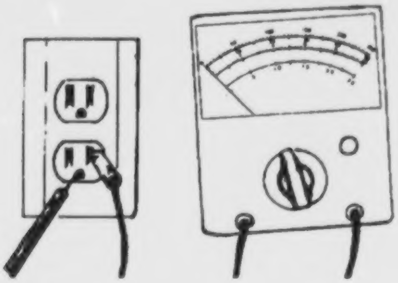
Job Sheet 3

☐ 5. Select meter scale that will allow for the most accurate reading.

☐ 6. Check from each side to ground and record your findings:

left, digital __________ left, analog __________

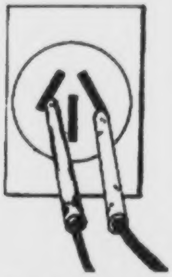
right, digital __________ right, analog __________



☐ 7. Switch to highest AC scale.

☐ 8. Check across a 240V wall outlet and record your findings:

digital __________ analog __________

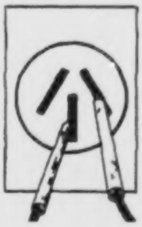


☐ 9. Select meter scale that will allow for the most accurate reading.

☐ 10. Check from each side to ground and record your findings:

left, digital __________ left, analog __________

right, digital __________ right, analog __________



Job Sheet 3

☐ 11. Switch to highest AC scale.

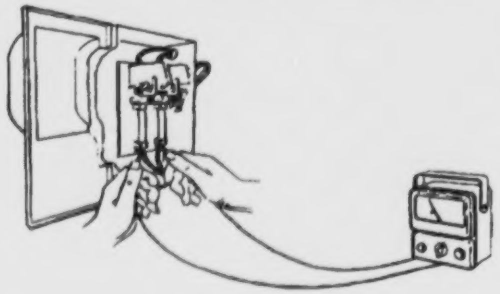
☐ 12. Check the line side of a fused disconnect and record your findings:

digital __________ analog __________

☐ 13. Select meter scale that will allow for the most accurate reading.

☐ 14. Check load side of the fused disconnect and record your findings:

digital __________ analog __________

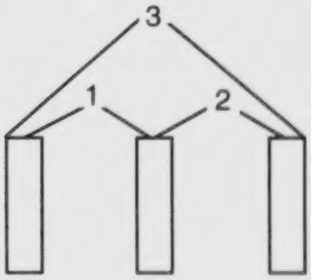


☐ 15. Check from each fused disconnect to ground and record your findings:

left, digital __________ left, analog __________

right, digital __________ right, analog __________

☐ 16. Repeat steps I I through 15; use the following graphic as a guide to check a three-phase fused disconnect, and record your findings:



	1: Left to Center	2: Right to Center	3: Left to Right
Line, digital	__________	__________	__________
Line, analog	__________	__________	__________
Load, digital	__________	__________	__________
Load, analog	__________	__________	__________

Job Sheet 3

Each Fused Disconnect to Ground

	Left	Center	Right
Digital			
Analog			

☐ 17. Have your instructor check your findings.

☐ 18. Return voltmeter and other materials to proper storage.

Comments ______________________________

Tools, Materials, and Test Instruments
Unit 2

Job Sheet 4—Use an Ohmmeter to Check Continuity of Fuses

Name ____ Attempt Number ______

Date____ Overall Rating________

Evaluation Criteria	**Rating**
Number of fuses evaluated as usable	________
Number of fuses evaluated as not usable	________
Proper application of digital ohmmeter	________
Proper appliction of analog ohmmeter	________

A. Tools and materials

Digital and analog ohmmeters
Plug and cartridge type fuses as selected and numbered by instructor
Pencil or pen for recording findings
Safety glasses

B. Procedure

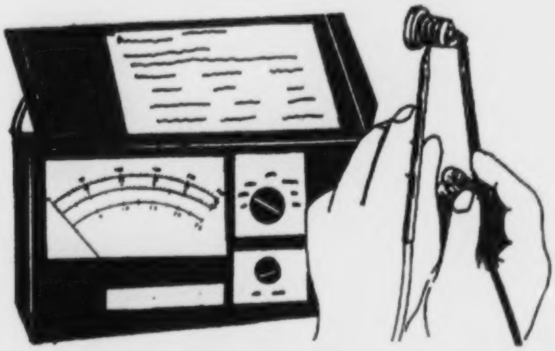
☐ 1. Put on safety glasses.

☐ 2. Select R x 1 scale on both meters.

☐ 3. Make sure all fuses are removed from their holders.

☐ 4. Touch one probe to outer metallic portion of plug type fuses.

☐ 5. Touch the other probe to the button on the bottom of the plug type fuses.



Job Sheet 4

☐ 6. Touch the ohmmeter leads to each end of cartridge type fuses.

☐ 7. Watch for a reading of zero ohms to indicate that the fuse has continuity and is usable.

☐ 8. Watch for a reading of ∞ (infinity) to indicate that the fuse does not have continuity and is not usable.

☐ 9. Record if fuses are usable or not usable.

Fuse 1 ______________________________

Fuse 2 ______________________________

Fuse 3 ______________________________

Fuse 4 ______________________________

Fuse 5 ______________________________

☐ 10. Have instructor check your findings.

☐ 11. Turn meters off and return tools and materials to proper storage.

Comments ______________________________

____

____

Tools, Materials, and Test Instruments
Unit 2

Job Sheet 5—Use an Ohmmeter to Determine Resistance of Resistors

Name ______________________________ Attempt Number ______

Date ______________________________ Overall Rating ________

Evaluation Criteria	Rating
Number of resistors evaluated	______
Number of resistors properly evaluated	______
Proper application of digital ohmmeter	______
Proper application of analog ohmmeter	______

A. Tools and materials

Digital and analog ohmmeters
Resistors as selected and numbered by instructor
Pencil or pen to record findings
Safety glasses

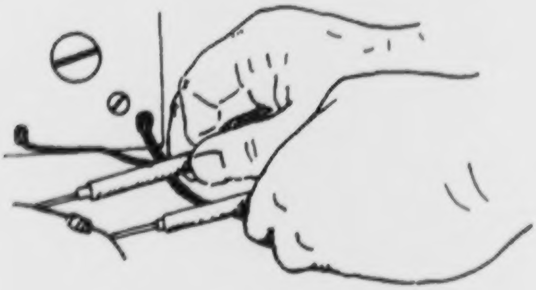
B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Select the highest ohm scale on the meters.

☐ 3. Zero meters.

☐ 4. Touch meter probes to resistor leads.



Job Sheet 5

☐ 5. Read the resistance on the ohmmeters, adjusting scale as necessary to obtain an accurate reading.

☐ 6. Record resistances:

Resistor 1 ____________________

Resistor 2 ____________________

Resistor 3 ____________________

Resistor 4 ____________________

Resistor 5 ____________________

☐ 7. Have your instructor check your findings.

☐ 8. Return tools and materials to proper storage.

Comments ____

____

____

Tools, Materials, and Test Instruments
Unit 2

Job Sheet 6—Use an Ohmmeter to Identify Terminals and Electrical Condition of a Hermetic Compressor

Name ______________________________ Date _______ Attempt Number ______

Evaluation Criteria	**Rating**
Sketch properly completed for testing reference	_____
Resistances read at proper terminals	_____
Start, run, and common terminals identified and labeled	_____
Compressor motor properly checked for open	_____
Compressor motor properly checked for short	_____
Compressor motor properly checked for ground	_____

A. Tools and materials

Digital and analog ohmmeters
Hermetic compressor as selected by instructor
Pencil or pen to record findings
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

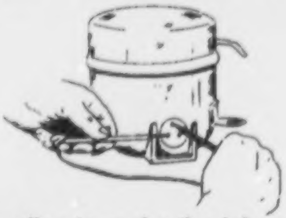
☐ 2. Select R x 1 scale on the ohmmeter.

☐ 3. Zero meter, if necessary.

☐ 4. In the space below, make a sketch of the compressor terminals, show the configuration, and label the terminals A, B, and C.

Job Sheet 6

☐ 5. Touch meter leads to the two compressor terminals you labeled A and B.



Note: Use alligator clips to make the job easier; your reading will be more accurate because there will be less resistance between the probes and the terminals.

☐ 6. Record resistance reading from A to B here: ________________.

☐ 7. Move the probe from termnal B to terminal C.

☐ 8. Record resistance reading from A to C here:________________.

☐ 9. Record resistance reading between B and C here:________________.

☐10. Indentify the start, run, and common terminals by labeling them on the sketch you drew on the previous page.

☐11. Select an ohmmeter scale that will read at least 100,000 ohms.

☐12. Zero the meter.

☐13. Touch one ohmmeter probe to one of the terminals and one of the probes to one of the,refrigerant line stubs or to the compressor shell, being careful to make good contact because dirt and paint are both insulators.

Note: If you found an open previously, you will have to repeat this check from each terminal.

☐14. Record your resistance reading here:___________.

☐15. Answer the following:

		Yes	No
(a)	Is there an open?	_____	_____
(b)	Is there a short?	_____	_____
(c)	is there a ground?	_____	_____

☐16. Have your instructor check your findings.

☐17. Return tools and materials to proper storage.

Comments____

____

____

Tools, Materials, and Test Instruments
Unit 2

Job Sheet 7—Use an Ammeter to Read Start and Run Amperage of a Motor

Name ______________________________ Attempt Number ______

Date ______________________________ Overall Rating ______

Evaluation Criteria	**Rating**
Digital and analog meters properly used	____
Starting amperage properly recorded	____
Running amperage properly recorded	____
Running amperage and FLA from nameplate compared	____

A. Tools and materials

Clamp-on ammeter
Motor or equipment as selected by instructor
Pen or pencil to record findings
Safety glasses

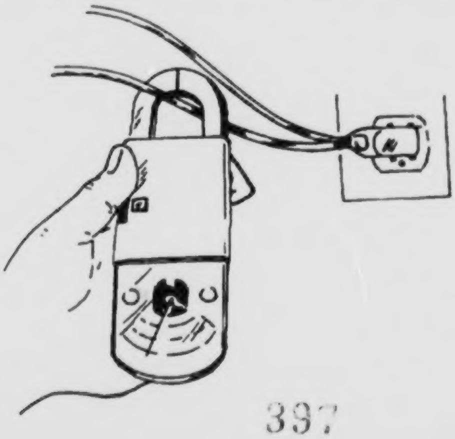
B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Select highest amperage scale.

☐ 3. Clamp the ammeter around one conductor of the power cord.

Note: If you place the ammeter around both conductors of a single-phase power source, you will cancel out the amperage reading.



Job Sheet 7

☐ 4. Adjust the ammeter scale to get the most accurate reading.

Note: Be ready to read the starting amperge because it will last only an instant after you start the equipment.

☐ 5. Start the equipment.

☐ 6. Read and record the starting amperage here:

digital __________ analog __________.

☐ 7. Allow the system to run.

☐ 8. Record the running amperage here:

digital __________ analog __________.

☐ 9. Check the F.L.A. on the motor nameplate and record it here: __________.

☐10. Compare the nameplate amperage to the running amperage recorded in Step 8.

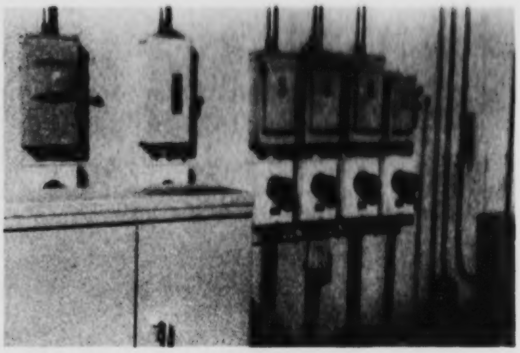
☐11. Evaluate your readings in a brief note to indicate if they agree, do not agree, are very close, are far enough apart to suggest a problem, etc.

Evaluation:____
____.

☐12. Have your instructor check your findings and your evaluation.

☐13. Secure test instruments and return tools and materials to proper storage.

Comments ____
____
____



Electrical Power

Unit 3

Objective Sheet

Unit Objective

After completing this unit, the student should be able to use Watt's Law to determine power, read a watt-hour meter, and use a wattmeter and an ammeter to determine watts. The student should demonstrate these competencies by completing the assignment and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to electrical power with their correct definitions.
2. Complete statements about characteristics of electrical power.
3. Select true statements about transformers.
4. Complete statements about power distribution.
5. Complete statements about power supplies.
6. Select true statements about delivery systems.
7. Complete statements about problems with power delivery.
8. Select true statements about power consumption.
9. Solve problems about Watt's Law.
10. Complete statements about measuring power consumption.
11. Complete statements about reading a watt-hour meter.
12. Use Watt's Law to determine power. (Assignment Sheet 1)
13. Read an electric watt-hour meter. (Assignment Sheet 2)
14. Use a wattmeter and an ammeter to determine watts. (Job Sheet 1)

Electrical Power
Unit 3

Information Sheet

1. **Terms and definitions**

   a. **Electric watt-hour meter**—A meter which indicates the number of kilowatt hours used in a given amount of time

   b. **Equipment ground**—Usually a green-colored or bare wire conductor connected to an equipment case and to an intentional ground for safety purposes

   c. **Ground conductor (ground)**—Usually a green-colored or bare wire system or circuit conductor which is intentionally grounded for safety purposes

   d. **Leg**—Term used to designate each hot conductor of a power supply

   e. **Neutral**—Usually a white current-carrying conductor connected to the center tap of a transformer which carries current only when an electrical device is operating

   Note: The neutral conductor is a current-carrying conductor and should not be confused with the ground conductor, even though the two may terminate at the same block.

   f. **Hot conductor**—In a circuit, it is a current-carrying conductor where voltage is always readable, and should be any color other than white, neutral gray, or green

   g. **Primary voltage**—Voltage supplied to the input or primary winding of a transformer

   h. **Secondary voltage**—Output voltage or voltage that is supplied from the secondary side of a transformer

   i. **Single-phase**—Alternating current with no more than two hot conductors

   j. **Step-down transformer**—A transformer which decreases secondary voltage

   k. **Step-up transformer**—A transformer which increases secondary voltage

   l. **Three-phase**—Alternating current with three hot conductors

   m. **Watt**—The fundamental unit of measurement for electrical power

Information Sheet

2. Characteristics of electrical power

a. To make life more comfortable, we use electrical power by converting it into such things as heat, light, and mechanical motion.

b. Electrical power is the time rate at which a charge is moved by voltage and is measured in watts:

(1) One watt equals the work accomplished in one second by one volt of potential difference in moving one coulomb of charge.

(2) One watt of electrical power equals 3.413 Btu's of heat.

(3) 746 watts equals one horsepower (hp).

3. Transformers

a. In order for electrical power to be used for heat, light, mechanical motion, and other uses, the proper voltage and current must be delivered over long distances to the home or business where it is needed.

b. Step-up transformers increase voltage at the point of generation, and step-down transformers decrease voltage at various other points in the delivery system.

c. Increasing the voltage in turn decreases the current which allows electrical power to be easily transmitted over long distances with relatively small transmission cable, since wire carrying capability is based on amperes.

Example: A modern total-electric home might require 30,000 watts. So, let's assume a primary voltage of 4,000 volts and secondary voltage of 240 volts.

$30{,}000 \div 240 = 125$ amperes, so entrance cable into the house must be large enough to carry in excess of 125 amperes.

$30{,}000 \div 4{,}000$ VAC $= 7.5$ amperes, so transmission cable to the primary of the transformer needs to be only large enough to carry 7.5 amperes.

d. Transformers within equipment are often used to reduce voltage even farther, down to 24 volts, 12 volts, or even 2.5 volts so that smaller wires can be used for controls such as room thermostats.

e. Transformers within equipment may increase voltage to as much as 5,000V DC for use with such devices as electronic air cleaners.

f. AC voltage may be converted by rectifiers within equipment to low level DC voltages, 5V, 10V, or 15V for use in electronic circuits.

Information Sheet

4. Power distribution

a. Electrical power begins at the power plant where falling water, burning coal or gas, or nuclear power is used to generate electrical power.

b. Step-up transformers immediately increase the voltage to as much as 345,000 volts in preparation for transmission.

c. Tranmission cables carry the power across country to regional sub stations where step-down transformers reduce the voltage to as low as 4,000 volts.

d. Transmission cables within the city or area carry the power to step-down transformers on power poles near residential and commercial/industrial customers.

e. These step-down transformers reduce the voltage to a level which can be used by the customer.

5. Types of power supplies

a. Residential and small commercial applications usually require only single-phase current in voltages ranging from 120 to 240.

b. Commercial and industrial applications may require three-phase current in various combinations of voltages ranging from 120 to 600.

c. Three-phase power can be used to supply single-phase power, but single-phase cannot be converted into three-phase power.

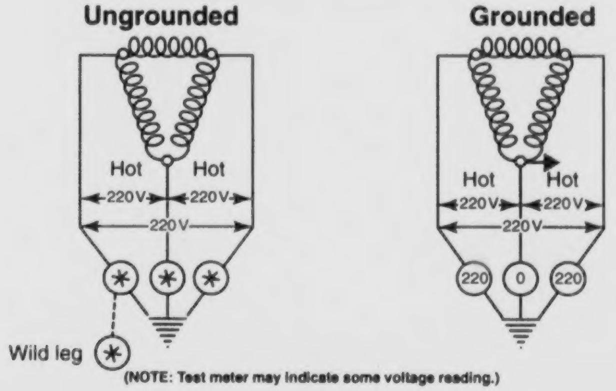
d. Using three-phase current to power motors avoids frequent requirements for starting components on single-phase motors and causes fewer motor service problems.

e. On the other hand, with three-phase current, voltage has to be kept in balance on all three legs.

f. Point-of-delivery transformers provide single- and/or three-phase current in various combinations of voltages:

(1) A three-wire delta transformer has one three-phase and three single-phase circuits with 240V, 440V, or 550V.

Three Wire Delta



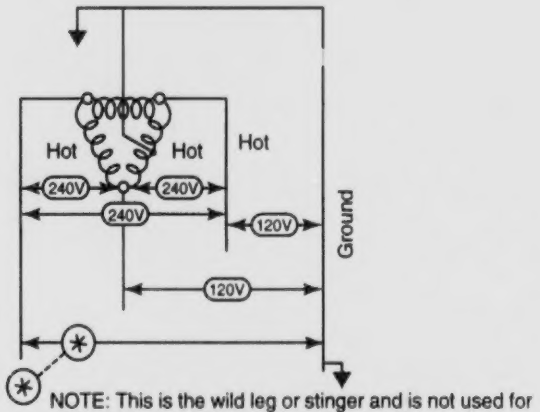
(NOTE: Test meter may indicate some voltage reading.)

Information Sheet

(2) A four-wire delta transformer has two 120V single-phase circuits, one 240V three-phase circuit, and three 240V single-phase circuits.

(3) The three legs include a "wild-leg" or "stinger-leg" as it is sometimes called, which has a voltage of approximately 200V which should **never** be used for single-phase 120V power.

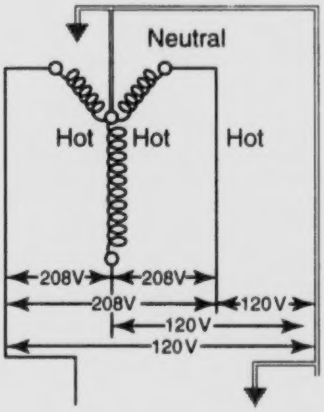
Four Wire Delta


Hot
Hot
Hot
240V
240V
240V
120V
120V
Ground
*
*

NOTE: This is the wild leg or stinger and is not used for 120v single-phase since its voltage is 200 volts.

(4) A four-wire wye transformer has three 120V or 277V single-phase circuits, three 208V or 480V single-phase circuits, and one 208V or 480V three-phase circuit.

Four Wire Wye

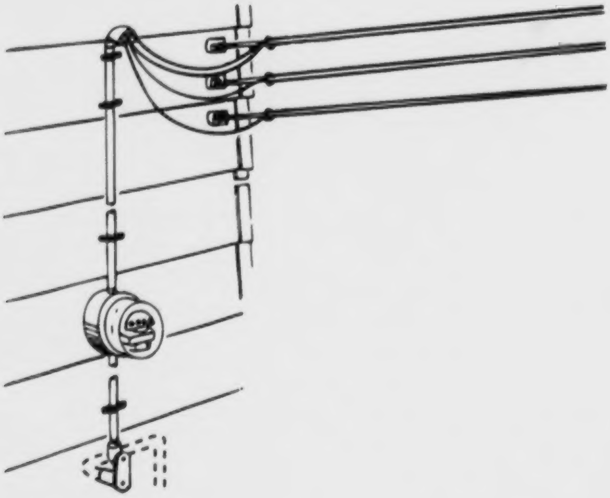

Neutral
Hot
Hot
Hot
208V
208V
208V
120V
120V
120V

g. Three-wire delta transformers may be grounded or ungrounded and four-wire wye transformers require that the transformer neutral be used for ground.

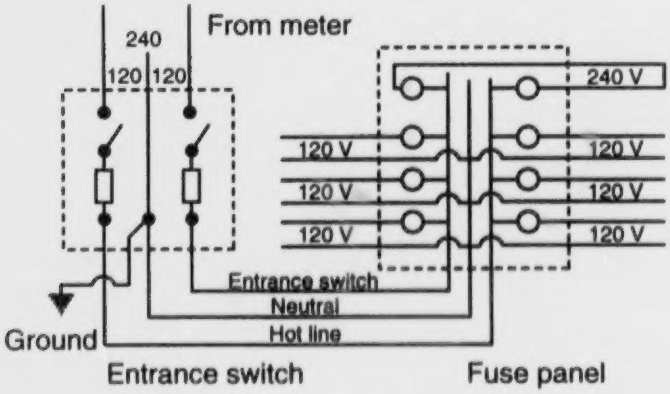
Information Sheet

6. Delivery systems

a. Service to a home or small business delivers power from a step-down transformer on a power pole through a watt-hour meter to a breaker or fuse panel.



b. The breaker panel, also called a circuit box, must include a single main breaker or fused disconnect switch and a separate breaker or fuse for each circuit in the building.

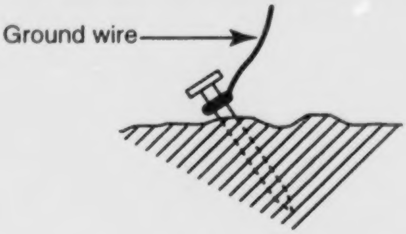

From meter
240
120
120
240 V
120 V
120 V
120 V
120 V
120 V
120 V
Entrance switch
Neutral
Hot line
Ground
Entrance switch
Fuse panel

c. 240V circuits will be connected to both hot legs and to the ground.

d. Individual 120V circuits will be parallel and connected to one hot leg, to neutral, and to the ground.

Information Sheet

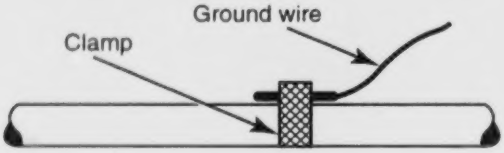
e. The system should be grounded from the connections in the watt-hour meter to a copper-clad, iron stake, usually 8 feet long, driven into the ground.



Grounding rod

f. The system may also be grounded to the cold-water piping in the building or through metallic conduit if it is used throughout the system.

Note: Cold water pipe grounding can only be used if the water lines are made of metal and not connected to plastic water lines.



Cold water pipe

7. **Problems with power delivery**

a. Problems in the supply service as well as within the building electrical system can cause low supply voltage.

b. The effects of low supply voltage can be seen in such things as:

(1) tripping breakers or blowing fuses.
(2) overheating of wiring and/or motors.
(3) motors having trouble starting or not starting at all.
(4) equipment operating at lower efficiencies.
(5) breakdown of motors or other electrical components.

c. Typical causes of low supply voltage include, but are not limited to:

(1) undersize transformer.
(2) undersize wire.
(3) long runs of wire.
(4) poor connections.
(5) loads in series.

Information Sheet

8. **Power consumption**

   a. Electrical loads can be said to consume or "use up" electricity.

   b. Power companies must determine how much electricity a load consumes in order to determine what to charge for the electricity.

   c. A power company measures the rate of flow of electricity to a customer by comparing the amperage draw of the service with the voltage provided over a specified period of time.

   d. The rate of flow, in effect, is the amount of heat, light, mechanical motion, or other work provided to the customer.

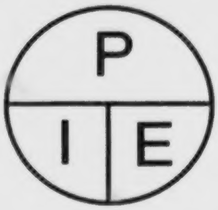
   e. The rate of flow is measured in watts per hour.

9. **Watt's Law**

   a. To calculate power (P) in an electrical circuit, use Watt's Law which is expessed by the basic formula:

      P (in watts) = I (amperes) x E (volts).

   b. Watt's Law is often presented graphically in a triangle or circle divided into three parts that represent the three elements in power relationships.



   c. This Watt's Law circle can be used just like the circle for Ohm's Law to find an unknown value.

      Note: See Assignment Sheet 1.

   d. Ohm's Law and Watt's Law are often used together to solve problems or determine unknown values.

   e. To find watts when only voltage and resistance are known, first use Ohm's Law to determine current, and then use voltage and current in Watt's Law to find P in watts.

Information Sheet

10. Measuring power consumption

a. A power company measures energy usage by the customer with a watt-hour meter which usually reads in kilowatts per hour (KWH).

b. Power company charges are normally based on the monthly KWH reading on a watt-hour meter mounted on an elctrical service entrance.

Note: See Objective 11 and Assignment Sheet 2.

c. A service technician measures wattage to help determine how efficiently or how close to specifications an appliance or component is operating.

d. A service technician may use a wattmeter to read watts, or use an ammeter and a voltmeter and Watt's Law to calculate watts.

e With a wattmeter, conversion factors for determing watt consumption are built-in so the technician is free of risking mistakes in calculations.

Note: See Job Sheet 1.

f. A power factor must be taken into consideration when using Watt's Law to calculate power consumption of motors or other inductive loads.

g. Watt's Law, including a power factor, is expressed by the formula:

$$P\text{ (watts)} = I\text{(amps)} \times E\text{(volts)} \times Pf\text{(power factor)}$$

h. Power factors for loads vary with the type of load:

(1) A resistive load has an approximate Pf of 1.0.

(2) Motors, have an approximate Pf of .75.

Note: Very small, fractional horsepower motors may have Pf's close to 1.0.

(3) Magnetic coils such as relays, contactors, and solenoids have an approximate Pf of .35.

Information Sheet

11. Reading a watt-hour meter

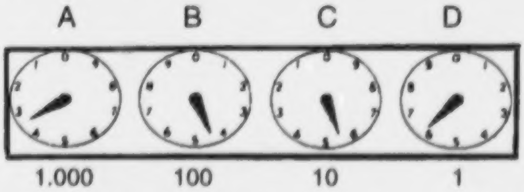
a. The electric watt-hour meter is used for both residential and commercial users to monitor energy consumption for a given time period.

b. Power companies use both digital and dial-type watt-hour meters.

c. Reading a digital meter is simply a matter of writing down the numbers shown on the face of the meter, but a dial-type meter requires a careful reading of the dials on the meter.

d. The dials have indicators that rotate clockwise or counterclockwise, so take care to observe which direction the indicator is rotating on the dial you are reading.

e. The indicator on the far left dial rotates counterclockwise, the dial indicator second from the left rotates clockwise, the next dial indicator rotates counterclockwise, and the far right dial indicator rotates clockwise.



f. Each dial is calibrated in graduations of base ten, the far left dial reads in thousands, the second dial from the left reads in hundreds, the next dial reads in tens, and the far right dial reads in ones.

g. Generally speaking, the number to read on each dial is the number the indicator has most recently passed.

h. Each dial reading should incorporate the quantities on the dial to its right.

Note: See Assignment Sheet 2.

i. To check on the operation and efficiency of electrical equipment, a technician can read the watt-hour meter at timed intervals and convert the reading into KWH usage and compare usage with specifications and test instrument readings made on the equipment.

j. Water meters and gas meters often employ the same type of dials and indicators as a watt-hour meter, and can be used by a service technician in a similar manner.

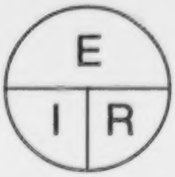
Electrical Power
Unit 3

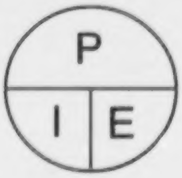
Assignment Sheet 1—Use Watt's Law to Determine Power

Name ______________________________ Overall Rating __________

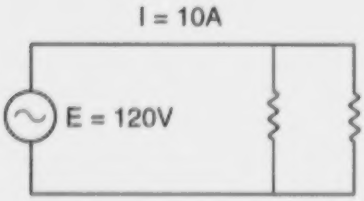
Evaluation Criteria	**Rating**
Number of problems attempted	_____
Number of problems properly solved	_____

Review: The following graphic representations of Watt's Law and Ohm's Law are the keys to solving power problems.



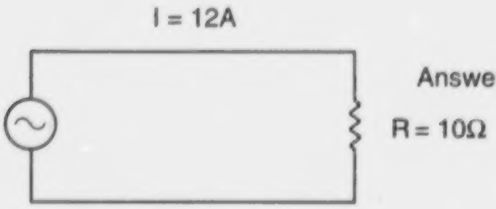


Example 1: Since P is unknown, covering up the P in the Watt's Law circle leaves I and E side by side, which means P = I x E. Substituting known quantities into the equation, gives P = 120 x 10 = 1200 watts.



Answer: P = 1200 watts or 1.2KW

Example 2: To find P when either I or E is unknown, go back to Ohm's Law and find the unknown value. In the following graphic, covering the unknown E in the Ohm's Law circle leaves I and R side by side which means E = I x R, or E = 12A x 10Ω = 120 volts. Using the 120V figure with Watt's Law, P = I x E gives P = 120V x 12A = 1,440 watts.

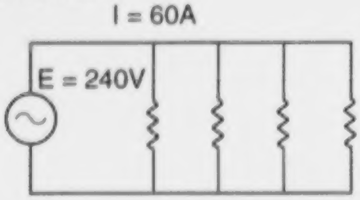


Answer: P = 1440 watts or 1.44KW

Assignment Sheet 1

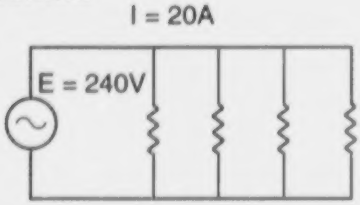
Directions: Use Watt's Law and Ohm's Law to solve the following problems:

Problem A



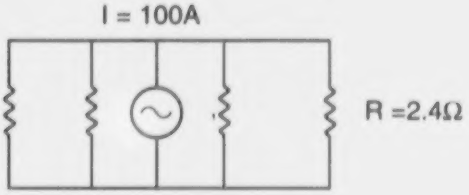
Answer: P = ___________

Problem B



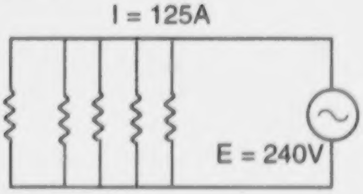
Answer: P = ___________

Problem C



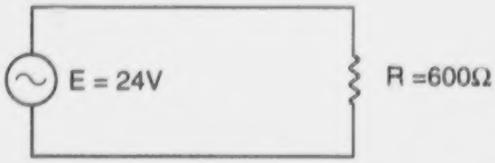
Answer: P = ___________

Problem D


I = 125A
E = 240V

Answer: P = ___________

Problem E



Answer: P = ___________

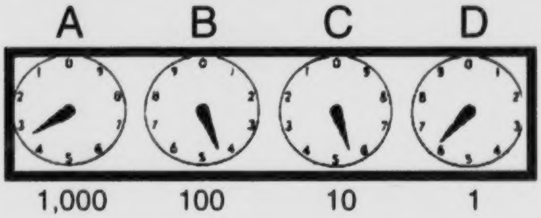
Electrical Power
Unit 3

Assignment Sheet 2—Read an Electric Watt-Hour Meter

Name ______________________________ Overall Rating ______

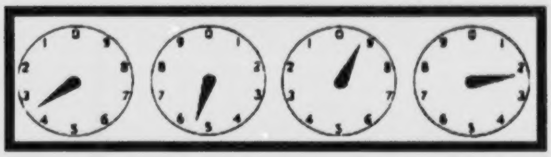
Evaluation Criteria	**Rating**
Meter readings properly made	______
Energy consumption properly calculated	______

Review: Read dials on a watt-hour meter from left to right, and by the number the indicator has just passed. The only time this is not true is when the indicator is loose and not pointing accurately, which is often the case on older meters.



In the illustration above, the indicator on Dial A has just passed 3, so the reading is 3. The indicator on Dial B has just passed 4, record the 4, and at this point, the reading is 34. On Dial C, the indicator has just passed 5, so our reading is now 345. On Dial D, the indicator has just passed 6, so our total reading becomes 3,456 KWH.

Now, let's check the result by reading the dials right to left: On Dial D, the indicator is barely past 6, so the Dial C indicator should be almost on 5. Since Dial C is slightly off, Dial B is also off and should be closer to 4, and Dial A should be closer to 3. The reading comes out the same, so the check proves our left-to-right reading to be correct. But the indicator on Dial B is probably loose, and had the indicator moved to the other side of 4, it could have affected the reading by as much as 100 KWH.



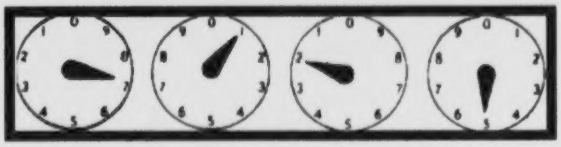
The watt-meter at the April reading reads 3,592 KWH, so the energy consumption for the March April billing period equals:

3,592
3,456
136 KWH

Assignment Sheet 2

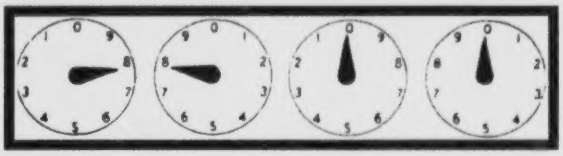
Directions: Refer to the review and the examples to complete the following.

Problem A Read the following dials



Answer________________

Problem B Read the following dials



Answer________________

Problem C Assume the two dials represent energy consmption for a one-month billing period. How many KWH did the customer use?

Answer________________

Electrical Power
Unit 3

Job Sheet 1—Use a Wattmeter and an Ammeter to Determine Watts

Name ________________________________ Attempt Number _____

Date ________________________________ Overall Rating _______

Evaluation Criteria	**Rating**
Initial readings properly made and recorded	_____
Wattmeter and voltmeter/ammeter properly used	_____
Readings completed and properly compared	_____

A. Tools and materials

Wattmeter
Voltmeter/ammeter
Amp multiplier or ten-wrap coil
Power consuming device selected by instructor
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

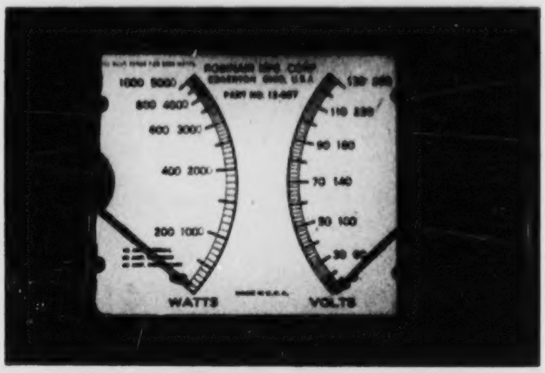
☐ 2. Read instructions supplied with wattmeter, if available, or consult with your instructor for operating instructions.

☐ 3. Read voltage rating and full load amperage or wattage rating on the unit nameplate and record: voltage _______; FLA or wattage ____________.

☐ 4. Measure line voltage of available source to make sure it matches nameplate voltage, and record: __________.

☐ 5. Set the wattmeter for the proper voltage to match the nameplate rating, and connect the wattmeter to line voltage.

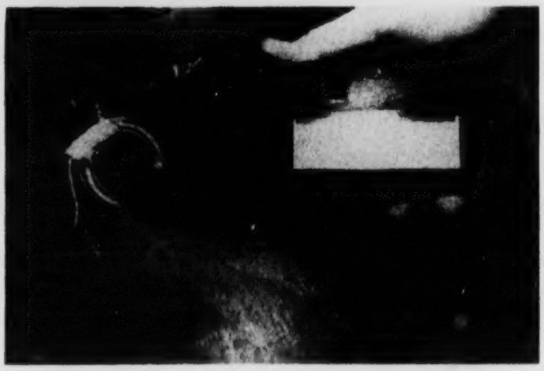
☐ 6. Select the highest wattage scale and connect power consuming device to the wattmeter.



Job Sheet 1

☐ 7. Place clamp-on ammeter around one of the power cord conductors or connect in-line ammeter to the device.

Note: An amp multiplier or ten-wrap coil may be necessary if the amp draw of the device is less than 2 or 3 amps; a combination ten-wrap coil and cord splitter will make this easier.



☐ 8. Have your instructor check your hookup.

☐ 9. Start the power consuming device, observe and record starting wattage: __________, and starting amps ________.

☐ 10. After the unit runs for a few minutes, select wattage and amperage scales that will allow for the most accurate readings, observe and record running wattage: __________, and running amps ___________.

☐ 11. Use Watt's Law to compare your amperage and wattage readings.

(a) Nameplate amperage converted to watts: ___________
(b) Nameplate wattage converted to amps: ___________
(c) Running amperage converted to watts (show your work in the space provided): ___________

Job Sheet 1

(d) Running wattage converted to amps (show your work in the space provided): __________

Note: If your device is an inductive load, you may need to consider Pf.

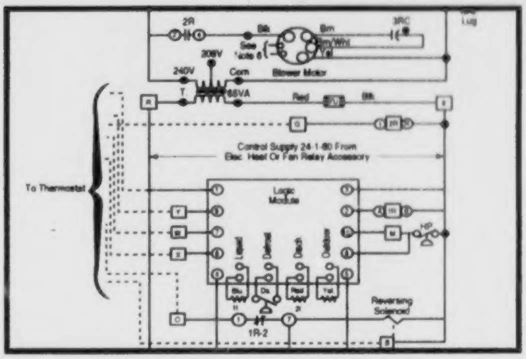
☐ 12. Discuss your findings with your instructor.

☐ 13. Return tools and materials to proper storage.

Comments: ____

____

____


2R
Blk
Brn
3RC
Lug
See Note 6
Brn/Wht
Yel
208V
240V
Com
Blower Motor
T
65VA
R
Red
Blk
G
2R
Control Supply 24-1-60 From
Elec. Heat Or Fan Relay Accessory
To Thermostat
Logic Module
Y
W
E
1R
HP
Reversing Solenoid
O
1R-2
B

Circuits, Symbols, and Diagrams

Unit 4

Objective Sheet

Unit Objective

After completing this unit, the student should be able to draw pictorial diagrams, fabricate working model circuits, and draw ladder schematic diagrams for series and parallel circuits, for series-parallel circuits, and for circuits with varied loads and switching. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to circuits, symbols, and diagrams with their correct definitions.
2. Complete statements about electronic circuits.
3. Select true statements about integrated circuits.
4. Complete statements about the language of electricity.
5. Select true statements about sources and applications of wiring diagrams.
6. Solve problems about pictorial wiring diagrams.
7. Solve problems about schematic wiring diagrams.
8. Complete statements about drawing a pictorial diagram.
9. Complete statements about building a ladder schematic diagram.
10. Differentiate between symbols used on pictorials and schematics.
11. Draw pictorials, fabricate working models, and draw ladder schematics for basic series and parallel circuits. (Job Sheet 1)
12. Draw pictorials, fabricate working models, and draw ladder schematics for series-parallel circuits. (Job Sheet 2)
13. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with varied loads and switching. (Job Sheet 3)

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Circuits, Symbols, and Diagrams
Unit 4

Information Sheet

1. **Terms and definitions**

    a. **Color coding**—The use of colored insulation around conductor wires to identify different wires or circuits and the marking of terminals with appropriate colors to assure connections are matched and to facilitate more efficient troubleshooting

    b. **Factory wiring**—Wiring installed at a factory

    c. **Field wiring**—Wiring installed in the field on a job site during installation or service

    d. **Installation diagram (electrician's diagram)**—A wiring diagram designed specifically to assist the installing electrician in connecting power to the equipment, but does not show internal wiring

    e. **Ladder schematic diagram**—A schematic diagram which resembles a ladder; the legs or siderails of the ladder represent the power supply and the individual parallel circuits form the rungs of the ladder

    f. **Legend**—Descriptive list of the components in a wiring diagram

    g. **Pictorial diagram (line or label diagram)**—A wiring diagram which shows pictures or representative drawings of electrical components in their approximate location in the equipment

    h. **Schematic diagram** —A wiring diagram which shows electrical components as symbols, how they function, and their order of operation

    i. **Symbol**—A drawing which represents a specific electrical or electronic component and its function

    j. **Wiring diagram**—A drawing of the electrical and/or electronic circuits within a piece of equipment or between pieces of equipment

Information Sheet

2. Electronic circuits

a. Electrical and electromechanical control circuits and devices are gradually being replaced by electronic devices and circuits.

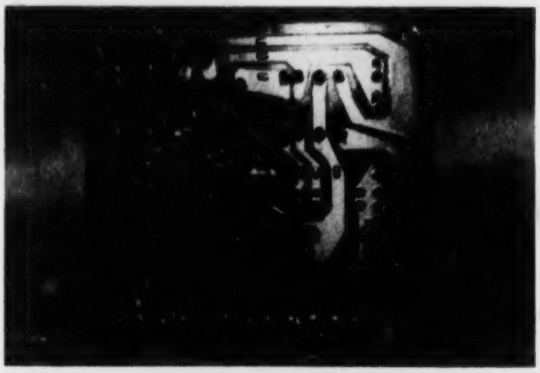
b. Electronic circuits are less expensive, more reliable, and provide more precise control.

c. Electrical circuits use AC voltages commonly ranging from 24V to hundreds of volts, and amperages ranging from a few tenths of an amp to tens of amps or even hundreds of amps.

d. Electronic circuits use DC voltages commonly ranging from 5V to 15V, and amperages measured in milliamps, thousandths of an amp, or even microamps, millionths of an amp.

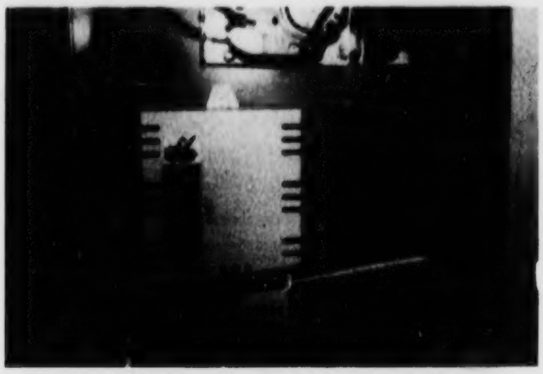
e. Most electronic circuits in the ACR field are mounted on printed circuit boards commonly called PC boards.

f. The desired circuit is laid out with copper foil on the back of the PC board and components such as resistors, capacitors, and relays are mounted on top of the PC board and soldered to the foil circuit.



Information Sheet

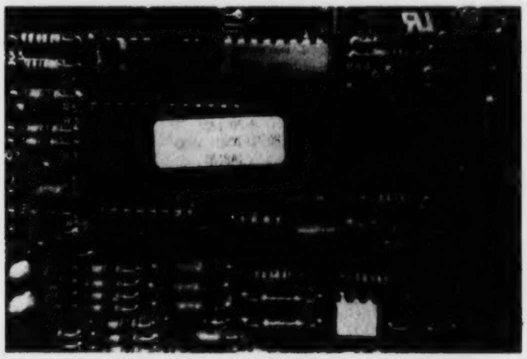
g. Some electronic circuits are PC boards and other electronic components are packaged in sealed modules commonly known as black boxes, although they are not always black.



h. Regardless of size, PC boards and modules are serviced by simply checking input and output voltages and replacing the entire board or module if any part of it has failed.

3. **Integrated circuits**

a. Integrated circuits commonly called chips or integrated circuit chips, or ICs, are often mounted on PC boards used as control boards in ACR systems.



b. A chip is a tiny wafer of semiconductor material containing microminiature, self-contained circuits designed to perform specific functions.

Example: Multifunction calculators, digital watches, and programmable digital thermostats all use IC chips.

c. The use of semiconductors in solid-state devices to make microminiature integrated circuits has made it possible for them to perform the same functions that used to require a room full of electronic equipment.

Information Sheet

d. The semiconductor device most responsible for this miniaturization is the transistor, consisting of a wafer of semiconductor material sandwiched between two layers of a different semiconductor material.

e. More complex integrated circuits called microprocessors are programmed to make decisions and perform complex tasks and are used in such devices as personal computers or electronic comfort system control centers.

4. The language of electricity

a. The use of symbols and wiring diagrams reduces long descriptions of electrical actions of ACR equipment to a kind of shorthand which a service technician must be able to read and interpret.

b. Symbols and diagrams are a little like a language with its own set of symbols for words and grammar-like structure.

c. A single electrical symbol will usually convey more informaton than a single word.

d. A single electrical symbol in a wiring diagram can tell a service technician such things as:

(1) whether the component is a source, load, path, or switch.

(2) how the component functions.

(3) how the component relates to other components.

(4) how the component is activated.

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Information Sheet

5. Sources and applications of wiring diagrams

a. When an ACR manufacturer (OEM) builds equipment, pictorial and schematic diagrams are usually affixed to the inside of unit panels or packaged with the equipment.

b. An installation diagram showing the proper electrical hookup to the equipment will also be packaged with the equipment.

c. After the installer sets the equipment in place, the electrician will use the installation diagram to connect source power to the unit.

d. A service technician will find the pictorial and schematic diagrams invaluable when starting the equipment initially or troubleshooting the equipment.

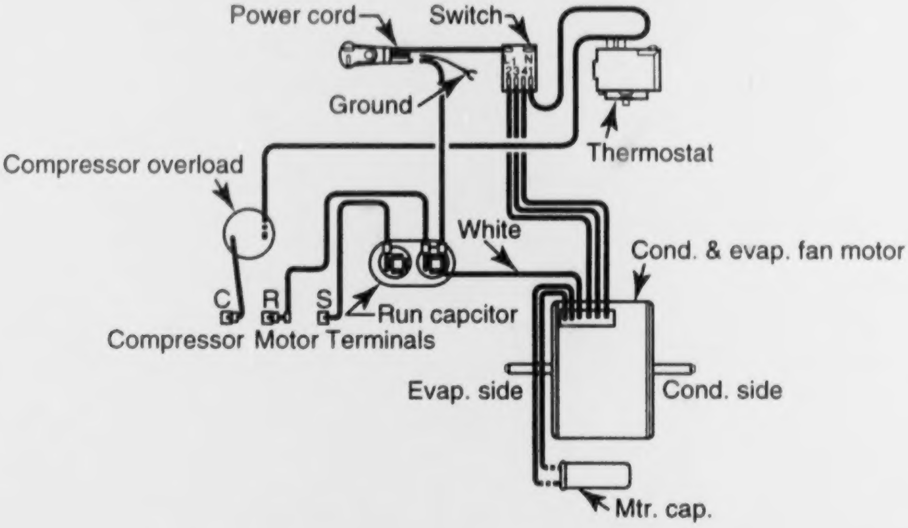
e. A service technician may need to sketch a rough version of a pictorial or schematic diagram if internal wiring has been altered or diagrams are missing.

f. A service technician may need to sketch a control diagram or connecting diagram to show how controls in system components are connected.

Example: OEM installation instructions may not show how to connect an air cleaner or humidifier into a residential system.

6. Pictorial wiring diagrams

a. Pictorial diagrams show system components as representative drawings or detailed reproductions, and show them in their approximate location.


Power cord
Switch
Ground
Thermostat
Compressor overload
White
Cond. & evap. fan motor
C
R
S
Run capcitor
Compressor Motor Terminals
Evap. side
Cond. side
Mtr. cap.

Information Sheet

b. Pictorial diagrams provide a good guide to field wiring because they show the components physical relation to one another and the color coding of the wires connecting them.

c. Because pictorial diagrams are designed to show physical relationships, circuits can be difficult to trace on a pictorial.

d. A good pictorial diagram will show, in some way, every wire, terminal, connector, and component in a piece of equipment.

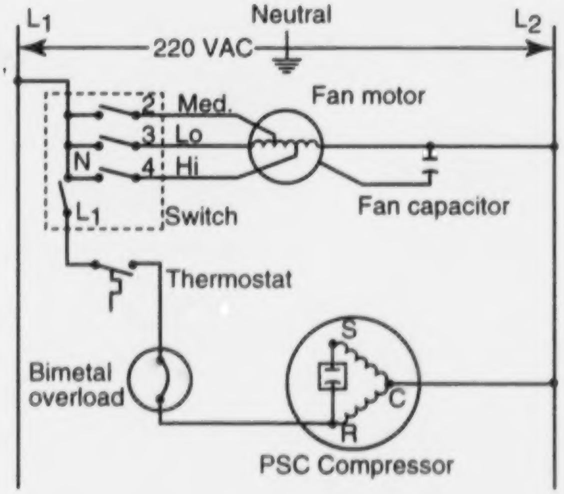
e. Pictorial diagrams help a service technician troubleshoot components and track down connections, but tracing an entire circuit can be difficult on a pictorial.

7. Schematic wiring diagrams

a. Schematic wiring diagrams show system components as symbols which show the function of the component.

b. Schematic diagrams show the order of operation of components rather than their location.

c. The most common type of schematic wiring diagram is the ladder diagram.



d. Schematic diagrams make circuit troubleshooting easy because the service technician can usually see at a glance which components are in each circuit, and their order of operation.

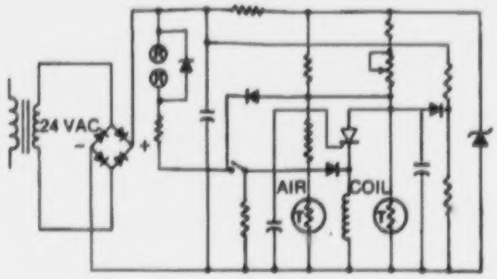
e. Because schematic diagrams do not show actual details of wires, terminals, and connectors, they are difficult to use for wire by wire troubleshooting, but are effective when used in conjunction with a pictorial.

Information Sheet

8. Electronic wiring diagrams

a. A special type of schematic diagram is used to show components.

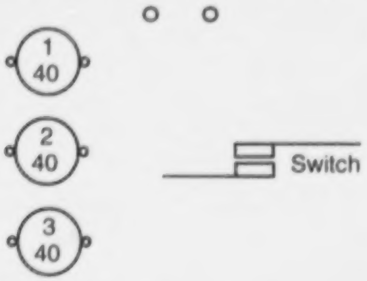
b. The electronic diagram is similar to, but not identical to the ladder schematic wiring diagram.



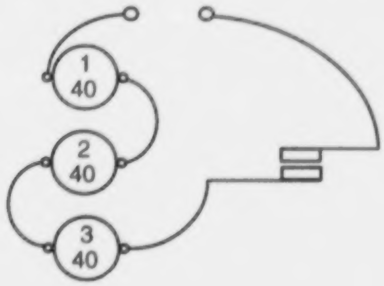
c. The use of semiconductors in electronic circuitry makes it difficult to trace an individual circuit because the routing of the circuit varies with changes in voltage or other conditions such as temperature, light, or pressure.

9. Drawing a pictorial diagram

a. Draw representative drawings of the components in their approximate locations or their relationships to each other.



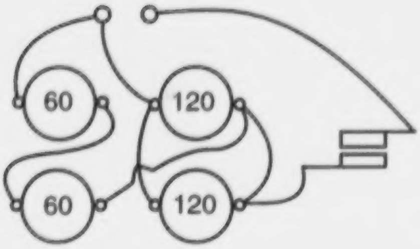
b. Draw lines to represent the wires connecting the components in such a way as to make the components operate as desired.



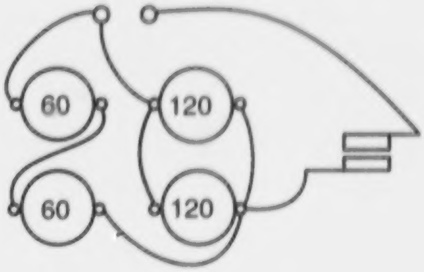
Information Sheet

c. Avoid wire crossings whenever possible.

Incorrect

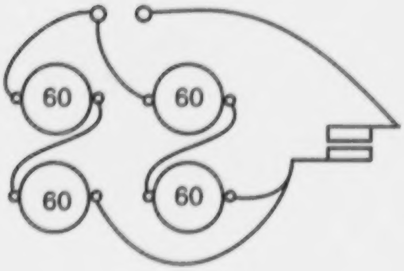

60
120
60
120

Correct

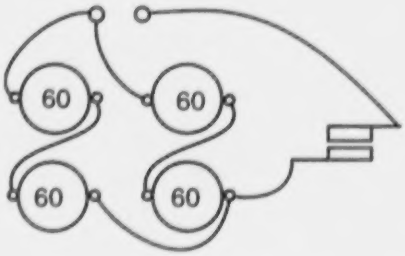

60
120
60
120

d. Avoid using two wires where one wire would do, and avoid using long wires where short wires would do.

Incorrect

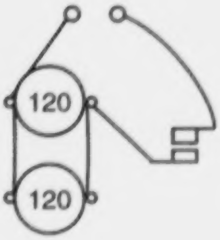


Correct

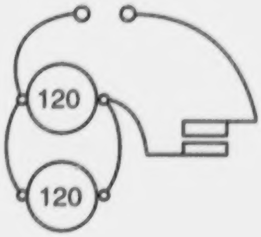


e. Avoid drawing wires too close to each other or too close to components.

Incorrect



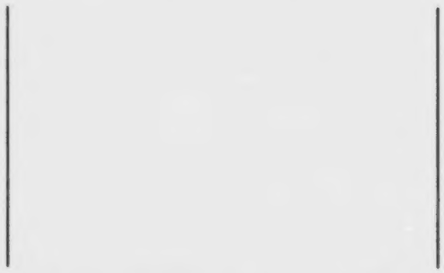
Correct



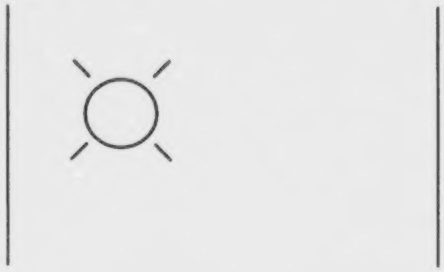
Information Sheet

10. Building a ladder schematic diagram

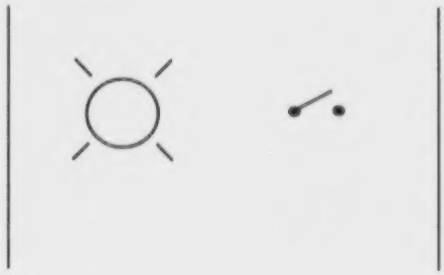
a. Locate and identify the power source on the pictorial diagram, and draw vertical lines or the "legs" of the ladder to represent the power source or sources.



b. Identify the load or loads in the pictorial diagram and draw them between the legs so that each load will be located on a separate rung of the ladder.

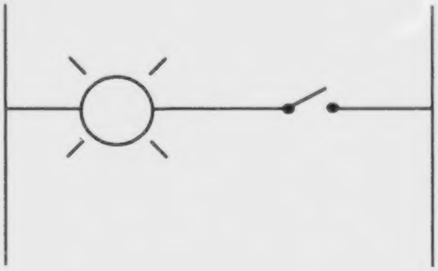


c. Identify the control or controls for each circuit in the pictorial, and draw the appropriate symbol so that it will be located on the same rung as the load it controls.



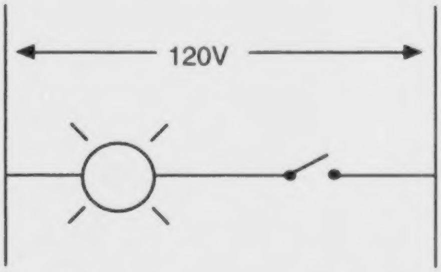
Information Sheet

d. Connect the components along the rungs with horizontal lines that connect to the legs.



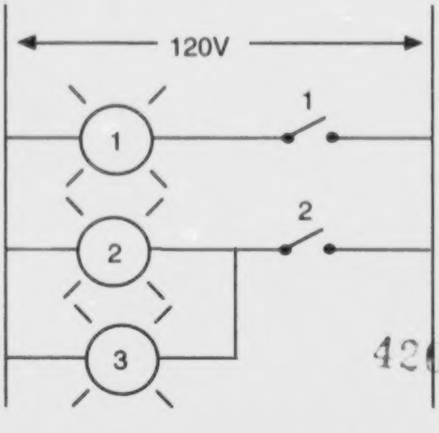
e. Label the source with the amount of voltage, and use arrows to identify the legs of the source voltage.

Note: Points of arrows should not touch the legs because they are not part of the circuit.



f. If symbols do not identify components or there are more components than one using the same symbol, the symbol must be labeled with a number, abbreviation, or other designation.

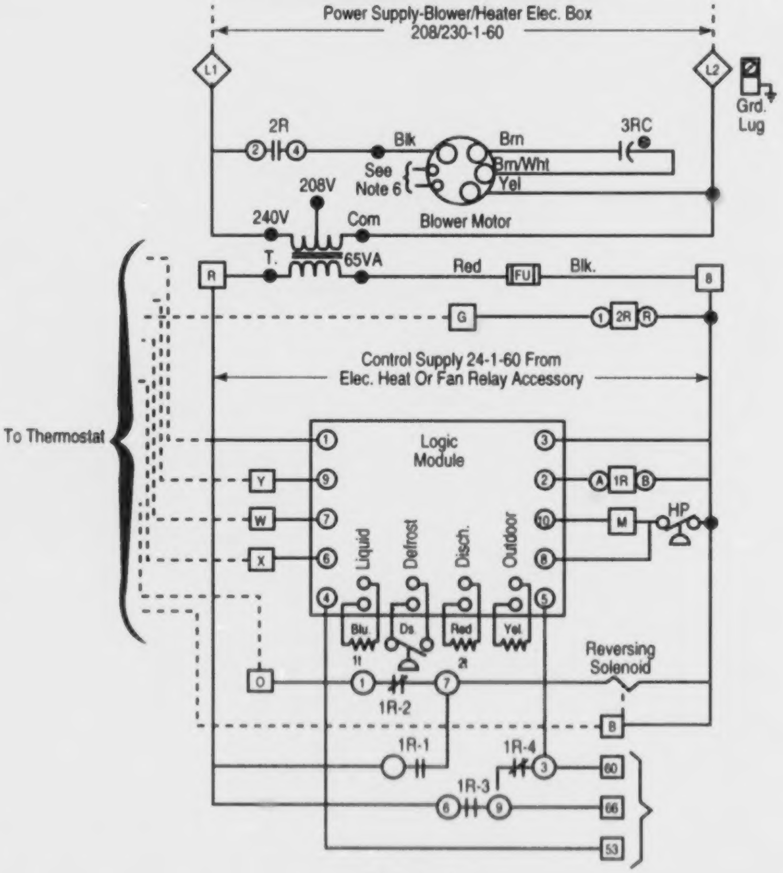
Note: In the following ladder schematic diagram, the loads are three lights controlled by two switches; note that loads and switches are numbered.



Information Sheet

g. Pictorials and schematics are often accompanied by legends to provide a key for properly interpreting labels and special entries by the OEM.

Heat Pump Wiring Diagram With Solid State Control Module


Power Supply-Blower/Heater Elec. Box
208/230-1-60
L1
L2
Grd. Lug
2R
Blk
Brn
3RC
See Note 6
Brn/Wht
Yel
208V
240V
Com
Blower Motor
T.
65VA
Red
FU
Blk.
R
B
G
2R
Control Supply 24-1-60 From Elec. Heat Or Fan Relay Accessory
To Thermostat
Logic Module
Y
W
X
1R
M
HP
Liquid
Defrost
Disch.
Outdoor
Blu.
Ds
Red
Yel.
1t
2t
Reversing Solenoid
O
1R-2
1R-1
1R-4
1R-3
60
66
53

Legend

1RC	Capacitor, Run, Compressor
2RC	Capacitor, Run, Prop. Fan Motor
3RC	Capacitor, Run, Blower Motor
HP	Control, High Pressure Open 400 PSIG. Close 300 PSIG
1R	Relay, Defrost
2R	Relay, Fan (Blower)
FU	Fuse 3.2 Amps
1t	Sensor, Liquid
2t	Sensor, Discharge
3t	Sensor, Ambient
DS	Switch, Defrost
CCH	Heater, Crankcase
+t°	Start Device
M	Contactor
TC	Thermostat, Cooling
TH	Thermostat,Heating
⊗	Identified Term. On Run Cap
☐	Terminal Block, 2TB, With Elec. Heat Or Fan Relay Accessory.
△	Terminal, Room Thermostat
——	Wiring & Devices By MFR
·····	Field Wiring By Others
◇	Connection, Blower/Heater Power Supply
----	Optional Wiring

Information Sheet

11. Using symbols

a. Both pictorial and schematic diagrams are often used side by side to describe the same piece of equipment.

a. The same components will appear on both diagrams, but they may be represented with different graphics.

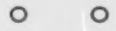
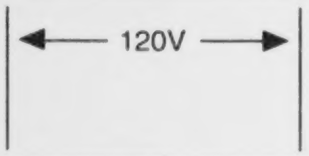
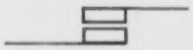
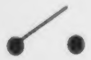
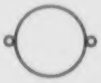
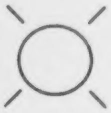
c. Graphics on pictorials may be simple symbols or may be drawings or pictures used to show the appearance of the component as well as its location.

d. Graphics on schematics should be symbols which show the function and operation of the component.

e. A comparison of pictorial and schematic symbols shows their similarities and their differences.

Note: You'll be working with all the following symbols in the job sheets that conclude this unit.

Basic Pictorial and Schematic Symbols

Symbol	Pictorial	Schematic
Source		
Manual Switch		
Light		

Circuits, Symbols, and Diagrams
Unit 4

Job Sheet 1—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Basic Series and Parallel Circuits

Name ______________________________ Attempt Number ________
Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Number of pictorials completed	______
Number of working models fabricated to specifications	______
Number of ladder schematics completed	______

A. Tools and materials

ACR technician's hand tools
Fabrication/wiring board w/loads selected by instructor
Conductors of various sizes
Fasteners as required
VOM or other test instrument
Safety glasses

B. Procedure

☐ 1. Put on safety glasses

☐ 2. Examine the graphics that follow on the next several pages and then continue in order to complete a pictorial diagram of each circuit so you can follow your diagram to fabricate the circuit as a working model and test it to prove it meets specifications.

☐ 3. After you fabricate and test the circuit, reference your working model and pictorial diagram as needed to draw a ladder schematic diagram to complete your work.

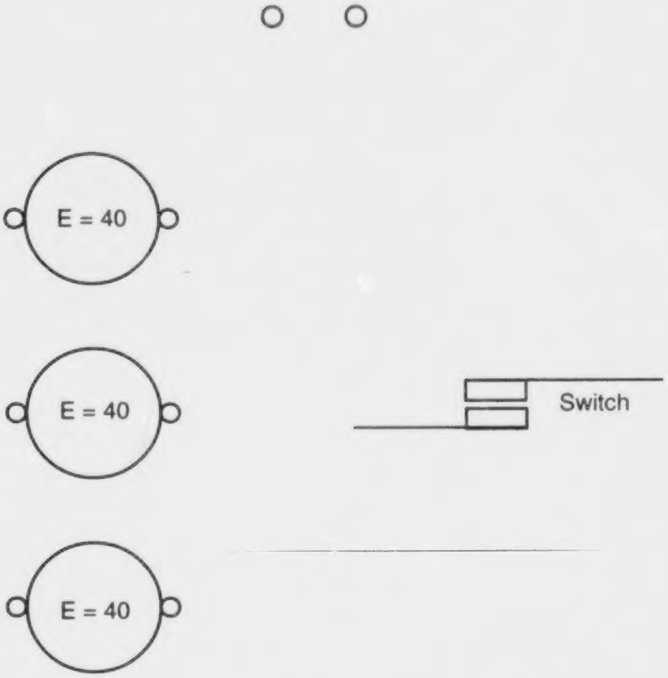
☐ 4. Follow all directions carefully; the pages are designed so that you can reference your pictorial diagram as you complete your ladder diagram.

☐ 5. Number loads and switches as needed, and read all the instructions before you begin so you can ask your instructor for clarification of any part of the job sheet that you do not understand.

☐ 6. Examine the following graphic and draw a pictorial diagram to the following specifications: the switch engages loads in a series circuit that will supply 40V to each load.

Job Sheet 1

Problem A: Pictorial



☐ 7. Use your pictorial diagram as a guide for fabricating a circuit to use as a working model.

☐ 8. Test the circuit to prove it meets specifications.

☐ 9. Have your instructor check your work.

☐ 10. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

430

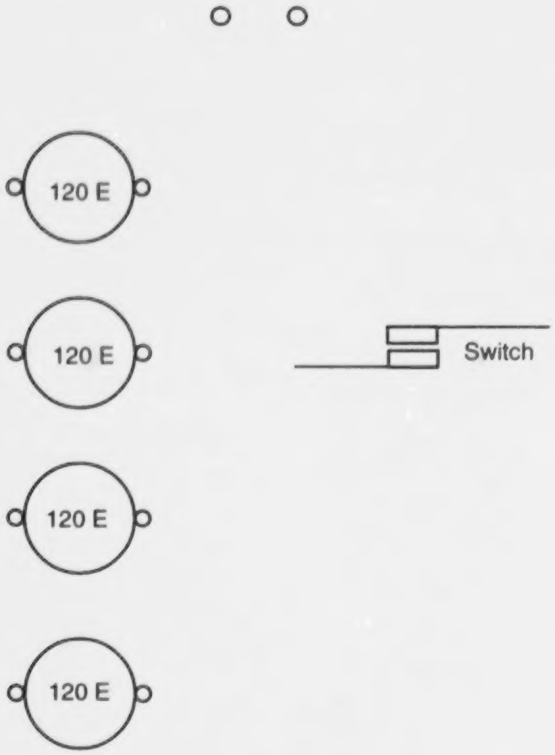
Job Sheet 1

Problem A: Ladder Schematic

☐ 11. Have your instructor check your ladder schematic diagram.

☐ 12. Examine the following graphic and draw a pictorial diagram to the following specifications: 120V will be present across each load, and the switch will be able to "make" or "break" the electron flow to all loads.

Problem B: Pictorial



☐ 13. Use your pictorial diagram as a guide to fabricate a circuit to use as a working model.

☐ 14. Test your circuit to prove it meets specifications.

☐ 15. Have your instructor check your work.

☐ 16. Use your working model and pictorial diagram as guides to complete a ladder diagram schematic in the space provided on the opposite page.

Job Sheet 1

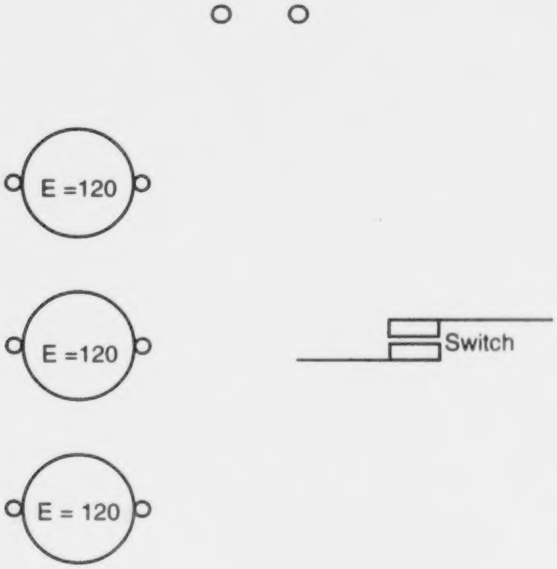
Problem B: Ladder Schematic

☐ 17. Have your instructor check your ladder schematic diagram.

Job Sheet 1

☐ 18. Examine the following graphic and draw a pictorial diagram to the following specifications: each load gets 120 volts and the switch controls electron flow to all loads.

Problem C: Pictorial



☐ 19. Use your pictorial diagram as a guide to fabricate a circuit to use as a working model.

☐ 20. Test your circuit to prove it meets specifications.

☐ 21. Have your instructor check your work.

☐ 22. Use your working model and pictorial diagram as guides to complete a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 1

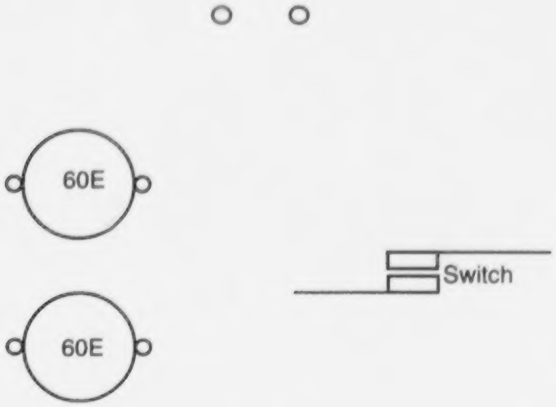
Problem C: Ladder Schematic

☐ 23. Have your instructor check your ladder schematic diagram.

Job Sheet 1

☐ 24. Examine the following graphic and draw a pictorial diagram to the following specifications: wire the loads in series so that when the switch is made each load receives 60V.

Problem D: Pictorial



☐ 25. Use your pictorial diagram as a guide for fabricating a circuit to use as a working model.

☐ 26. Test the circuit to prove that it meets specifications.

☐ 27. Have your instructor check your work.

☐ 28. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 1

Problem D: Ladder Schematic

☐ 29. Have your instructor check your ladder schematic diagram.

Comments ____

____

____

____

Circuits, Symbols, and Diagrams
Unit 4

Job Sheet 2—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Series-Parallel Circuits

Name______________________________ Attempt Number______
Date______________________________ Overall Rating________

Evaluation Criteria	Rating
Number of pictorials completed	_____
Number of working models fabricated to specifications	_____
Number of ladder schematics completed	_____

A. Tools and materials

ACR technician's hand tools
Fabrication/wiring board w/loads selected by instructor
Conductors of various sizes
Fasteners as required
VOM or other test instrument
Safety glasses

B. Procedure

☐ 1. Put on safety glasses

☐ 2. Examine the graphics that follow on the next several pages and then continue in order to complete a pictorial diagram of each circuit so you can follow your diagram to fabricate the circuit as a working model and test it to prove that it meets specifications.

☐ 3. After you fabricate and test the circuit, reference your working model and pictorial diagram as needed to draw a ladder schematic diagram to complete your work.

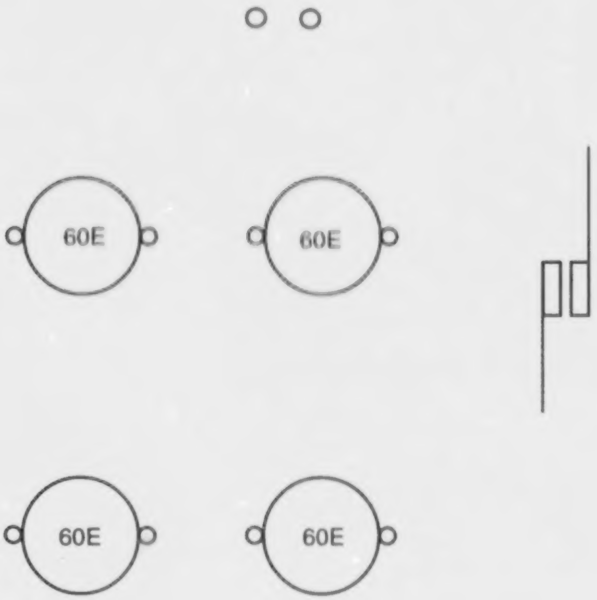
☐ 4. Follow all directions carefully; the pages are designed so that you can reference your pictorial diagram as you complete your ladder diagram.

☐ 5. Number loads and switches as needed, and read all the instructions before you begin so you can ask your instructor for clarification of any part of the job sheet that you do not understand.

Job Sheet 2

☐ 6. Examine the following graphic and draw a pictorial diagram to the following specifications: each load receives 60V with loads in series and circuits in parallel to form a series-parallel circuit with one switch used to "make" and "break" the four loads.

Problem A: Pictorial



☐ 7. Use your pictorial diagram as a guide for fabricating the circuit as a working model.

☐ 8. Test the circuit to prove that it meets specifications.

☐ 9. Have your instructor check your work.

☐ 10. Use your working model and your pictorical diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

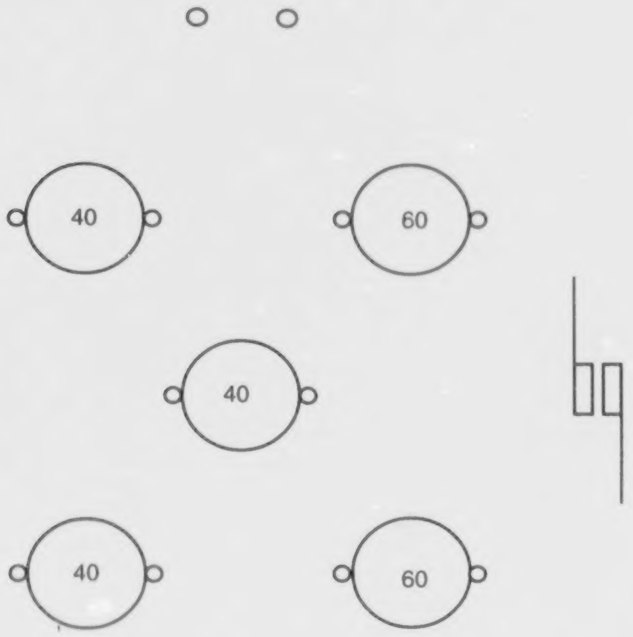
Problem A: Ladder Schematic

☐ 11. Have your instructor check your ladder schematic diagram.

Job Sheet 2

☐ 12. Examine the following graphic and draw a pictorial diagram to the following specifications: loads wired so that three loads get 40V each and the remaining two loads get 60V each when the switch is closed.

Problem B: Pictorial Diagram



☐ 13. Use your pictorial diagram as a guide for fabricating a circuit to use as a working model.

☐ 14. Test your circuit to prove that it meets specifications.

☐ 15. Have your instructor check your work.

☐ 16. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

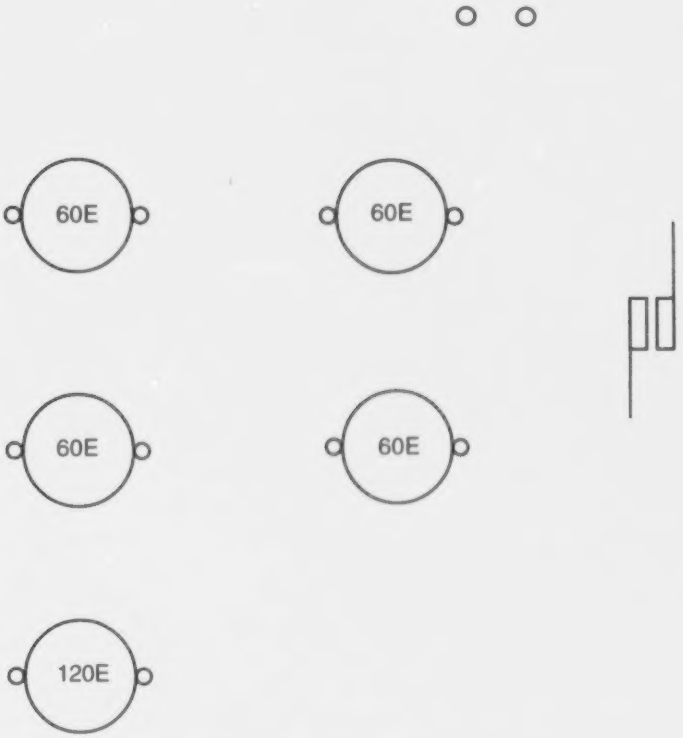
Problem B: Ladder Schematic

☐ 17. Have your instructor check your ladder schematic diagram.

Job Sheet 2

☐ 18. Examine the following graphic and draw a pictorial diagram to the following specifications: four loads receive 60V each and one load receives 120V when the switch is closed.

Problem C: Pictorial



☐ 19. Use your pictorial diagram as a guide for fabricating a circuit to use as a working model.

☐ 20. Test your circuit to prove that it meets specifications.

☐ 21. Have your instructor check your work.

☐ 22. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

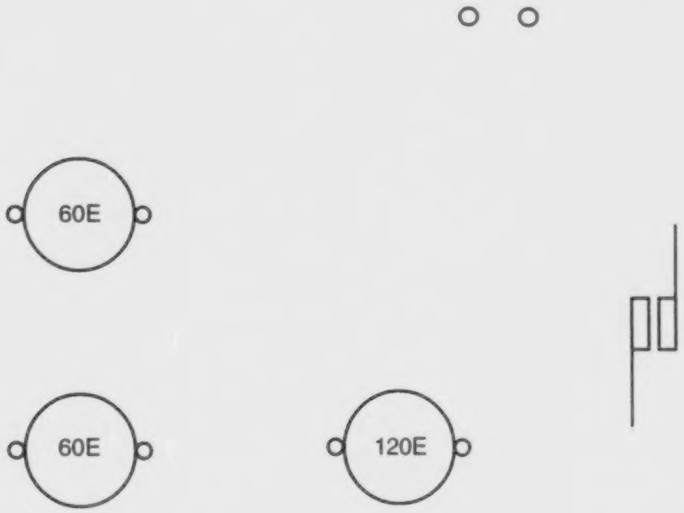
Problem C: Ladder Schematic

☐ 23. Have your instructor check your ladder schematic diagram.

Job Sheet 2

☐ 24. Examine the following graphic and draw a pictorial diagram to the following specifications: one switch "makes" or "breaks" electron flow to two loads that require 60V and a third load that requires 120V.

Problem D: Pictorial



☐ 25. Use your pictorial diagram as a guide for fabricating a circuit to use as a working model.

☐ 26. Test the circuit to prove it meets specifications.

☐ 27. Have your instructor check your work.

☐ 28. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

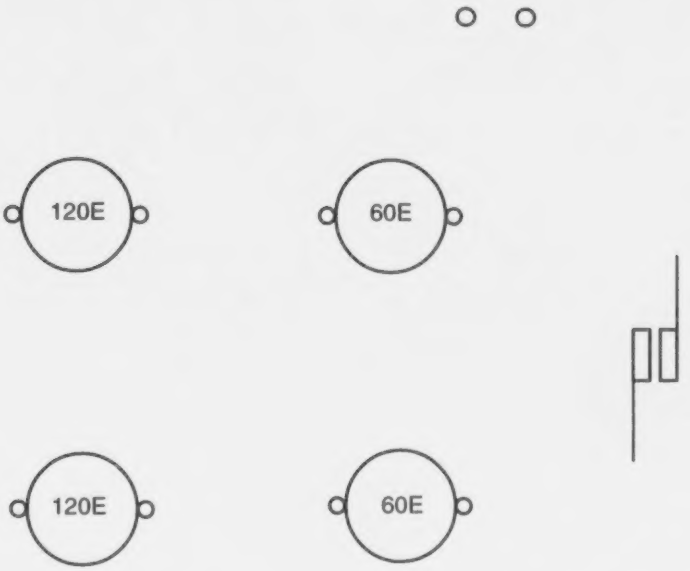
Problem D: Ladder Schematic

☐ 29. Have your instructor check your ladder schematic diagram.

Job Sheet 2

☐ 30. Examine the following graphic and draw a pictorial diagram to the following specifications: one switch "makes" or "breaks" electron flow to two loads of 60V and two more loads of 120V.

Problem E: Pictorial



☐ 31. Use your pictorial diagram as a guide for fabricating a circuit to use as a working model.

☐ 32. Test the circuit to prove it meets specifications.

☐ 33. Have your instructor check your work.

☐ 34. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

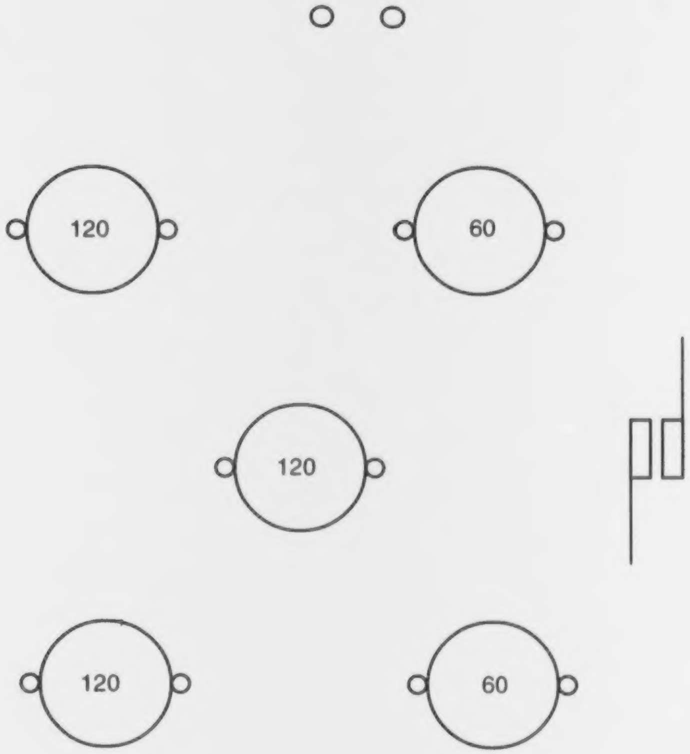
Problem E: Ladder Schematic

☐ 35. Have your instructor check your ladder schematic diagram.

Job Sheet 2

☐ 36. Examine the following graphic and draw a pictorial diagram to the following specifications: one switch "makes" or "breaks" electron flow to five loads, three of which receive 120V and the other two receive 60V.

Problem F: Pictorial



☐ 37. Use your pictorial diagram as a guide for fabricating a circuit to use as a working model.

☐ 38. Test the circuit to prove it meets specifications.

☐ 39. Have your instructor check your work.

☐ 40. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

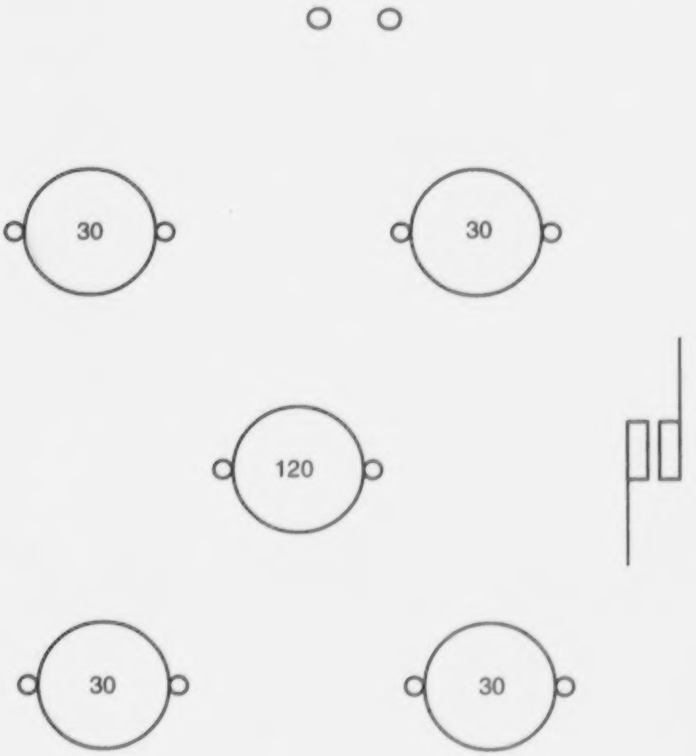
Problem F: Ladder Schematic

☐ 41. Have your instructor check your ladder schematic diagram.

Job Sheet 2

☐ 42. Examine the following graphic and draw a ladder diagram to the following specifications: arrange the loads to give four loads 30V and the remaining load 120V. All loads must be controlled by the switch.

Problem G: Pictorial



☐ 43. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 44. Test your circuit to prove it meets specifications.

☐ 45. Have your instructor check your work.

☐ 46. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

Problem G: Ladder Schematic

☐ 47. Have your instructor check your ladder schematic diagram.

Comments ____

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Circuits, Symbols, and Diagrams
Unit 4

Job Sheet 3—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Circuits With Varied Loads and Switching

Name______________________________ Attempt Number________
Date______________________________ Overall Rating________

Evaluation Criteria	**Rating**
Number of pictorials completed	______
Number of working models fabricated to specifications	______
Number of ladder schematics completed	______

A. Tools and materials

ACR technician's hand tools
Fabrication/wiring board w/loads selected by instructor
Conductors of various sizes
Fasteners as required
VOM or other test instrument
Safety glasses

B. Procedure

☐ 1. Put on safety glasses

☐ 2. Examine the graphics that follow on the next several pages and then continue in order to complete a pictorial diagram of each circuit so you can follow your diagram to fabricate the circuit as a working model and test it to prove it meets specifications.

☐ 3. After you fabricate and test the circuit, reference your working model and pictorial diagram as needed to draw a ladder schematic diagram to complete your work.

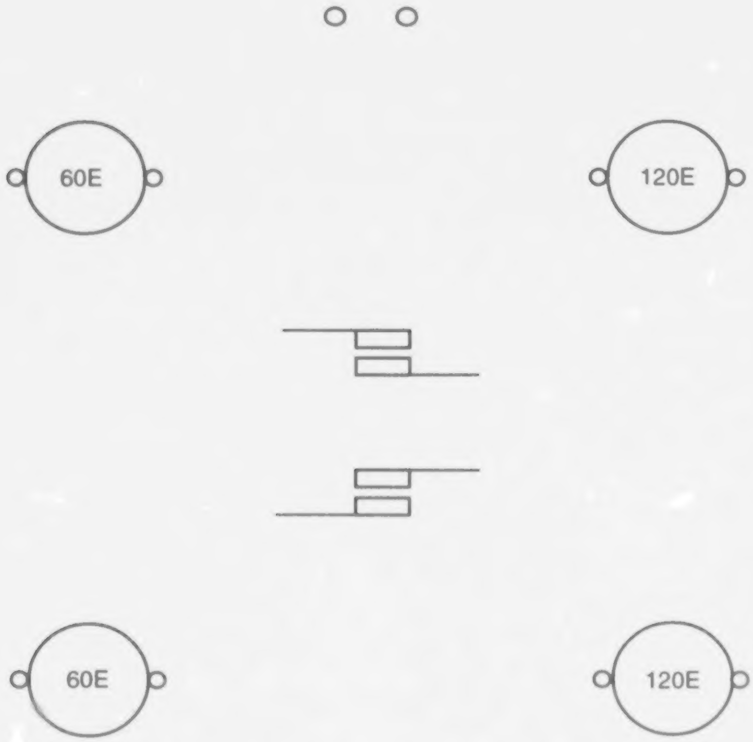
☐ 4. Follow all directions carefully; the pages are designed so that you can reference your pictorial diagram as you complete your ladder schematic.

☐ 5. Number loads and switches as needed, and read all the instructions before you begin so you can ask your instructor for clarification of any part of the job sheet that you do not understand.

Job Sheet 3

☐ 6. Examine the following graphic and draw a pictorial diagram to the following specifications: either switch when "made" will distribute 60V to two of the loads, and 120V tc each of the other two loads, and although one switch can "make" the circuit, both switches have to be off to "break" the circuit.

Problem A: Pictorial



☐ 7. Use your pictorial diagram as a guide for fabricating a circuit to use as a working model.

☐ 8. Test the circuit to prove that it meets specifications.

☐ 9. Have your instructor check your work.

☐ 10. Use your working model and your pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 3

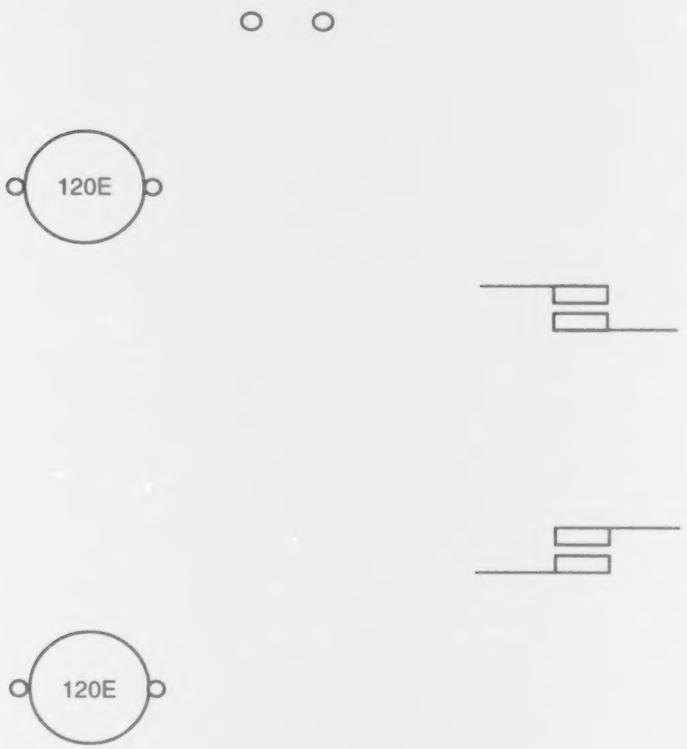
Problem A: Ladder Schematic

☐ 11. Have your instructor check your ladder schematic.

Job Sheet 3

☐ 12. Examine the following graphic and draw a pictorial diagram to the following specifications: Either switch will allow 120V to be applied to both loads at the same time, but both switches have to be open to "break" the circuit.

Problem B: Pictorial



☐ 13. Use your pictorial diagram as a guide to fabricate a circuit to use as a working model.

☐ 14. Test your circuit to prove that it meets specifications.

☐ 15. Have your instructor check your work.

☐ 16. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 3

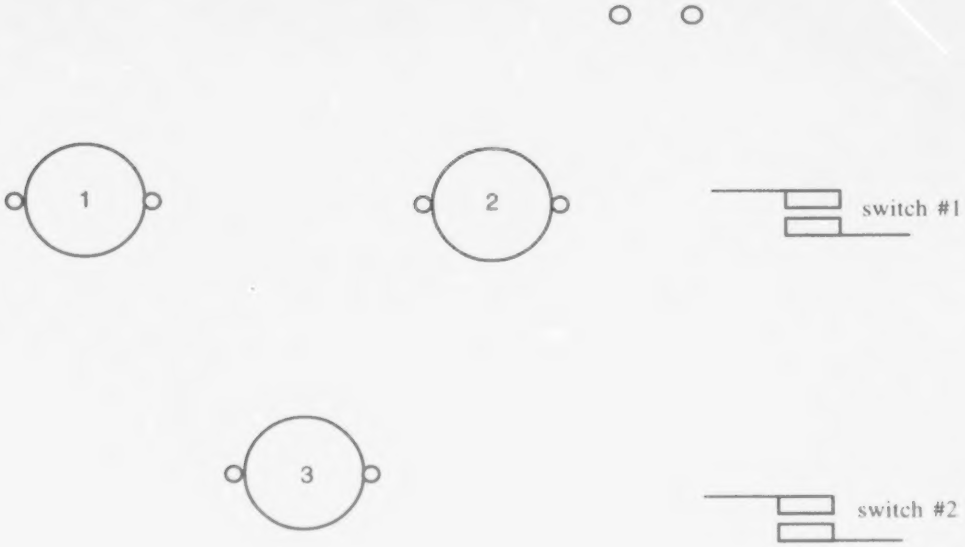
Problem B: Ladder Schematic

☐ 17. Have your instructor check your ladder schematic diagram.

Job Sheet 3

☐ 18. Examine the following graphic and draw a pictorial diagram to the following specifications: Switch #1 gives Loads 1 and 2 120V each while Switch #2 gives Load 3 120V, but only if Switch #1 is closed.

Problem C: Pictorial



☐ 19. Use your pictorial diagram as a guide to fabricate a circuit to use as a working model.

☐ 20. Test your circuit to prove that it meets specifications.

☐ 21. Have your instructor check your work.

☐ 22. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 3

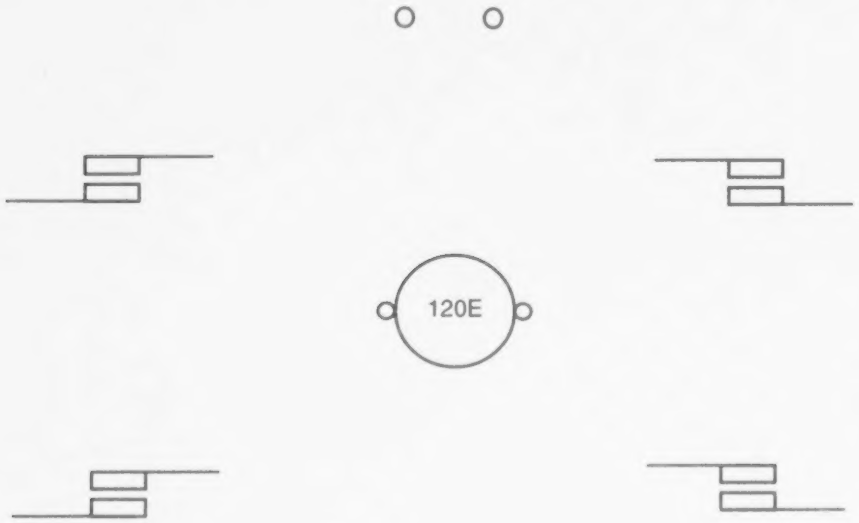
Problem C: Ladder Schematic

☐ 23. Have your instructor check your ladder schematic diagram.

Job Sheet 3

☐ 24. Examine the following graphic and draw a pictorial diagram to the following specifications: any one of the switches can "make" the load, but all four switches must be open to "break" the load.

Problem D: Pictorial



☐ 25. Use your pictorial diagram as a guide to fabricate a circuit to use as a working model.

☐ 26. Test your circuit to prove that it meets specifications.

☐ 27. Have your instructor check your work.

☐ 28. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 3

Problem D: Ladder Schematic

☐ 29. Have your instructor check your ladder schematic.

Comments ____

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Controls and Protection Devices

Unit 5

Objective Sheet

Unit Objective

After completing this unit, the student should be able to draw pictorials, fabricate working models, and draw ladder schematics for shunt circuits with one SPST switch, for circuits with 3-way switches, for circuits with 3-way and 4-way switches, and for circuits with safety switches. The student should demonstrate these competencies by completing activities in the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to protection and control devices with their correct definitions.
2. Select true statements about controls and their applications.
3. Complete statements about types of controls.
4. Complete statements about control systems.
5. Complete statements about switch configurations and symbols.
6. Identify switch symbols.
7. Complete statements about applications of shunt circuits.
8. Select true statements about electronic switching.
9. Select true statements about protection devices.
10. Identify overcurrent protection devices.
11. Complete statements about pressure-actuated protection devices.
12. Select true statements about motor protection devices.

Objective Sheet

13. Complete statements about bimetal protection devices.

14. Complete statements about protecting electronic devices.

15. Draw pictorials, fabricate working models, and draw ladder schematics for shunt circuits with one SPST switch. (Job Sheet 1)

16. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with 3-way switches. (Job Sheet 2)

17. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with 3-way and 4-way switches. (Job Sheet 3)

18. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with safety switches. (Job Sheet 4)

19. Draw a pictorial, fabricate a working model, and draw a ladder schematic of a basic refrigerator circuit. (Job Sheet 5)

Controls and Protection Devices
Unit 5

Information Sheet

1. **Terms and definitions**

   a. **Automatic reset protection device**—A control that resets itself after conditions that caused a circuit interruption have ceased

   b. **Circuit breaker**—A resettable overcurrent protection device that resembles a switch

   c. **Control**—Any device that operates or regulates electrical and mechanical systems

   d. **Fuse**—A nonresettable overcurrent protection device which contains elements or an element which melts and opens a circuit at a specified amperage

   e. **Line duty control**—A device that controls or interrupts a line voltage circuit

   f. **Manual reset protection device**—A control that must be reset manually after it has interrupted a circuit

   g. **Overcurrent protection**—A device in a circuit that limits the amperage to a specified amount

   h. **Pilot duty control**—A device that controls or interrupts a control circuit

   i. **Protection device**—Any device that protects the equipment or circuit from excessive conditions that could damage equipment, harm people, or impair operation

   j. **Switch**—Any device used to open and/or close an electrical circuit

2. **Controls and their applications**

   a. Almost all electrical and mechanical devices have some means for stopping and starting their operation.

   b. The simplest control is a plug which is inserted into and removed from an electrical outlet.

   Example: Less expensive model soldering irons have no on/off switch; they start when they are plugged into a wall outlet.

   c. Most controls are some type of electrical switch.

Information Sheet

d. Control devices are categorized as primary controls, operating controls, or limit controls.

e. Primary controls respond to operating controls and cycle or operate the equipment or system which affects conditions.

Example: The contactor which energizes and deenergizes the compressor and condenser fan is a primary control.

f. Operating controls respond to conditions and cycle or operate primary controls.

Example: The thermostat which energizes and deenergizes the contactor is an operating control.

g. Limit controls limit the maximum and/or minimum conditions under which equipment will operate.

Example: The high pressure switch which deenergizes the contactor when refrigerant pressures exceed safe operating conditions is a limit control.

3. **Types of controls**

a. Control devices are designed to operate manually or to operate by responding to changes in temperature, pressure, liquid or gas flow, liquid level, or the passage of time.

b. **Manual controls** include on/off switches, start/stop switches, thermostat sub-base switches and others that have to be manually operated.

c. **Temperature controls** include thermostats, furnace fan controls, high temperature limits, and others that respond to changes in temperature.

d. **Pressure controls** include low-pressure operating controls, high- and low-pressure safeties, condenser fan cycling controls, and others that respond to changes in pressure.

e. **Flow controls** include air cleaner cycling controls, hydronic heating safeties, gas furnace vent fan safeties, and others that respond to changes in liquid or gas flow.

f. **Liquid level controls** include sump pump float switches, boiler overflow safeties, water-cooled condenser safeties, and others that respond to changes in liquid level.

g. **Time controls** include setback thermostats, defrost controls, and others that respond to the passage of time.

Information Sheet

4. Control systems

a. A control system includes the conditioned area, the controlling instruments, and the operating device or devices.

b. The conditioned area is the area in which the temperature, pressure, humidity, and other conditions are being controlled.

c. Controlling instruments are instruments that respond to changes in the conditions in the conditioned area, instruments such as thermostats, motor controls, pressurestats, and humidistats.

d. Operating devices are the mechanisms that directly affect the actual conditions, devices such as valves, dampers, fans, and compressors.

e. Types of control systems include:

(1) electric.
(2) pneumatic.
(3) electronic.
(4) fluidic.
(5) combinations of the above.

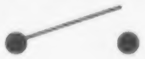
5. Switch configurations and symbols

a. Switches may connect and/or disconnect a circuit by using contact points, knifeblade contacts, mercury in a tube, solid state devices, and other means.

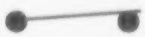
b. Switch contacts are rated by the amount of current they will carry at various voltages.

Example: 8A @ 115V and 3A @ 230V.

c. Normally open (NO) switches have the contacts separated when there is no power in the circuit or under normal operations, and a NO switch "makes" when the contacts are brought together; the symbol for a NO switch is:

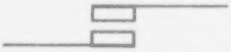


d. Normally closed (NC) switches have the contacts touching when there is no power in the circuit, or under normal operation, and an NC switch "breaks" when the contacts are separated; the symbol for a NC switch is:

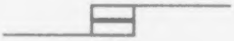


Information Sheet

e. A switch that breaks at only one end, such as a simple manual switch, is referred to as single break or single make; the pictorials for single break or single make switches are:

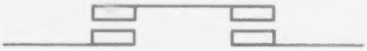


Single Make



Single Break

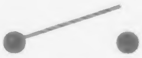
f. A switch that breaks at both ends, such as a unit contactor, is technically a double make, but technicians often refer to it as a double break; the pictorial is:



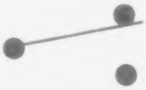
g. The number of legs of electricity that a switch can handle is described as its "pole," single pole, double pole, triple pole, or more.

h. The number of positions a switch can be placed in, not counting "off" positions or the number of circuits a leg can be connected to, is described as its "throw," single throw, double throw, or more.

Examples:
single pole, single throw, normally open, SPST NO

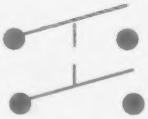


single pole, double throw, SPDT

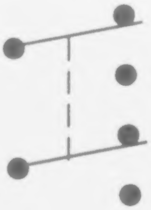


i. In symbols, dotted lines are used to connect switches tied together to act as single controls.

Examples:
double pole single throw, normally open, DPST NO



double pole, double throw, DPDT



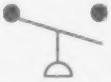
Information Sheet

6. Identifying switch symbols

a. Switch symbols usually describe what a switch responds to, physical pressure or a condition such as temperature, pressure, or liquid level.

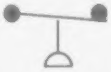
b. The following are common switch symbols and their descriptions:

(1) SPST close on pressure rise



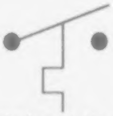
Examples: Condenser fan cycling controls, compressor cycling control, and others.

(2) SPST open on pressure fall



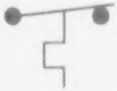
Examples: Low-pressure or loss-of-charge protector.

(3) SPST close on temperature fall



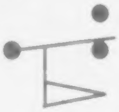
Examples: Heating thermostats, defrost thermostats, and others.

(4) SPST open on temperature rise



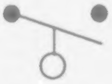
Examples: Furnace limit switches, boiler safeties, and others.

(5) SPDT change on increase in flow (left to right)



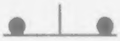
Examples: Humidifier and air cleaner activation switches and others.

(6) SPST close on liquid level rise



Examples: Sump pump switches, overflow safeties, and others.

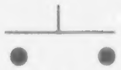
(7) SPST double break NC push button



Examples: Refrigerator light switch, stop switches, and others.

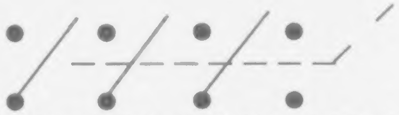
Information Sheet

(8) SPST double make NO push button



Example: Start switches, blower door safety switches, and others.

(9) TPST disconnect



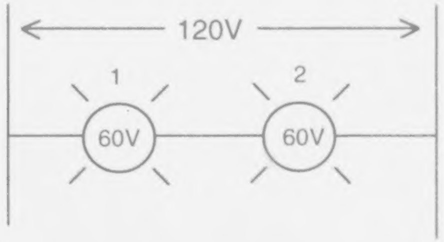
Examples: Three-phase condensing unit disconnect and others.

7. Applications of shunt circuits

a. Shunt circuits "shunt" current around a load by taking advantage of the fact that electrical current takes the path of least resistance.

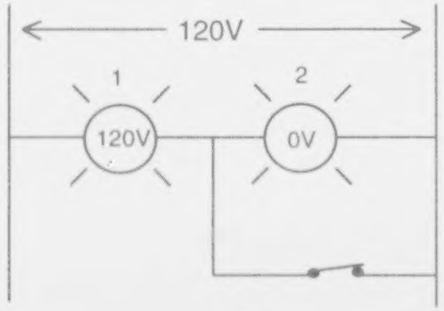
b. When loads placed in series are connected to a power source, the voltage drop at each load is in proportion to its resistance.

Example: In the following diagram, note two light bulbs of the same wattage hooked up to a 120V power source, each with a 60V voltage drop.



c. A switch can be used to route or shunt electricity around one of the loads causing the load to turn off, even though the load is not disconnected from the source.

Example: In the following diagram, note that light 1 has a 120V voltage drop and light 2 has no voltage drop because the current takes the path with the switch in it because that path has less resistance than light 2.



Information Sheet

d. In the example in item c, note that light 2 is off when the switch is "on" and that light 2 is on when the switch is "off"; remember that even when light 2 is not on it is still connected to the power source.

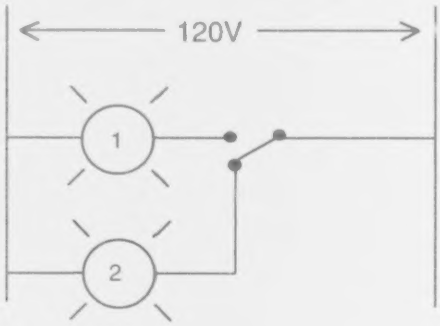
e. In a technical sense, the switch in the above examples should be referred to as "open" or "closed" rather than "off" or "on."

f. Note that light 2 in the above examples goes on and off, but light 1 receives different amounts of voltage but never goes off.

g. Variations of the shunt circuit are used in control circuits such as lock-in or lock-out circuits, defrost circuits, and ice maker harvest circuits.

h. Multiple position switches often direct the current to one or more of several alternative paths rather than simply turning loads on or off.

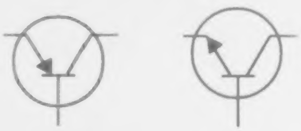
Example: In the following example, a single pole, double throw switch can be used to energize either light 1 or light 2.



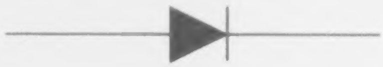
8. **Electronic switching**

a. Electronic circuits use semiconductor devices to perform control and switch functions.

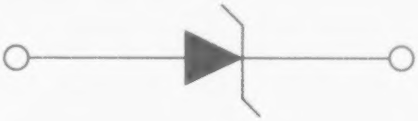
b. Current flow in a transistor is controlled by the voltage applied at the junction of the dissimilar materials.



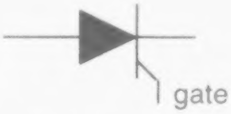
c. Current flow through a diode is in one direction only, and if you apply AC voltage to a diode, it will conduct only on each positive AC half-cycle.



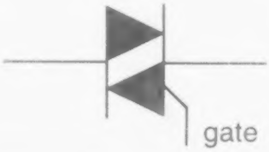
d. Current flow through a zener diode takes place only when a specified voltage threshold is reached.



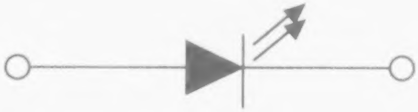
e. Current flow through an SCR, silicon-controlled rectifier, is in one direction only and takes place only when a specified voltage threshold is reached at the gate.



f. Current flow through a TRIAC, which is two SCRs combined, is in both directions and takes place only when a specified voltage threshold is reached at the gate.



g. To form numbers and/or letters, indicators on control panels use special light emitting diodes, LEDs, which give off light when current passes through them.



9. Protection Devices

a. Protection devices are specialized switches used to protect equipment or circuits from excessive conditions.

b. Protection devices respond to conditions such as excessive current, low or high pressures, or high or low temperature.

c. Some single protection devices respond to more than one condition, not in combination, but in an either/or situation such as high or low pressure triggering the same switch.

d. Protection devices may be automatic reset, manual reset, or have to be replaced to be reset.

Information Sheet

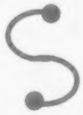
10. Overcurrent protection devices

a. Overcurrent protection devices include fuses, circuit breakers, fusible links, and some types of overloads.

b. Overcurrent protection devices respond to excessive current with links that melt to physcially break a circuit or by opening a set of contacts to break a circuit.

c. The National Electric Code sets standards for overcurrent protection devices, and devices that do not meet the NEC standards should not be used.

d. Fuses contain a current limiting link that melts if current exceeds a set amount, and fuses are identified by the following symbol:

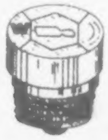


e. Time-delay fuses are designed to carry approximately double the set amount of current for a very short time before they open the circuit.

f. Some fuses are made so that the link can be replaced, but generally a blown fuse must be replaced with a new fuse twisted or snapped into place.

g. Common types of fuses include:

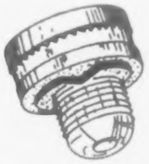
(1) Edison base plug fuses.



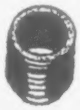
(2) Type S plug fuses.

Note: Adapters are available for using a type S fuse in an Edison base plug fuse socket.

Type S fuse



Adapter

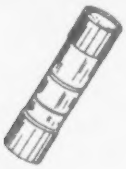


Information Sheet

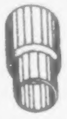
(3) Ferrule-type cartridge fuses.

Note: Fuse holders are designed for different amperages, and adapters can be used to fit small amperage fuses into larger amperage holders, but not the reverse.

Ferrule-type cartridge fuse



Adapter

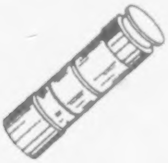


(4) Cartridge fuses with replaceable fuse links.

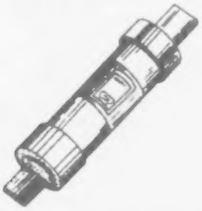
Note: The ends of the cartridge screw off to permit replacement of a fuse link.

(5) R-rejection cartridge fuses.

Note: R-rejection cartridges will fit into standard ferrule-type holders, but standard ferrule-type fuses will not fit into R-rejection holders.

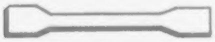


(6) Blade-type cartridge fuse.

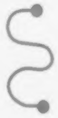


h. A fusible link operates just like a fuse, but is bolted, screwed, or soldered into place.

Fusible link

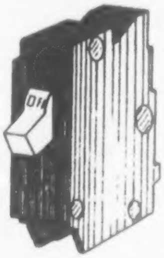


Symbol



Information Sheet

i. Circuit breakers contain a bimetallic strip or trigger which heats up and bends when current exceeds the breaker setting, and trips a set of contacts to open the circuit.



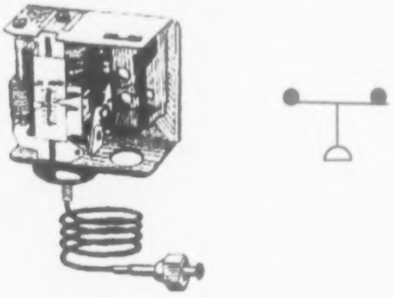
11. **Pressure-actuated protection devices**

a. Refrigerant pressure controls interrupt the compressor motor circuit or the compressor motor control circuit if refrigerant pressure drops below or exceeds control settings.

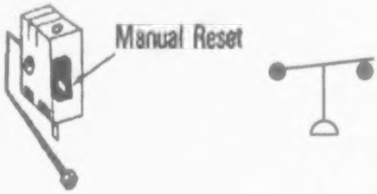
b. Refrigerant pressure controls may have a manual reset or an automatic reset.

c. Refrigerant pressure controls may be high pressure, low pressure, or both high and low pressure controls combined in a dual pressure control.

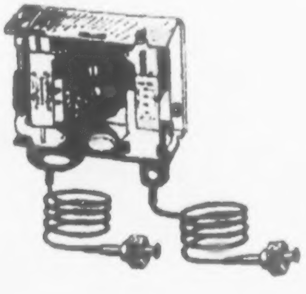
Refrigerant low pressure switch and symbol



Refrigerant high pressure switch and symbol

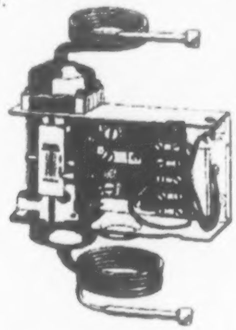


Refrigerant dual pressure switch



Information Sheet

d. An oil pressure control connects to both the oil pump and the compressor motor crankcase to monitor the difference between the oil pressure and the crankcase pressure.



e. An oil pressure control interrupts the compressor motor circuit or the compressor motor control circuit when the pressure differential drops below the factory setting.

Note: The differential of the oil pressure switch is set at the factory and should not be adjusted in the field.

12. **Motor protection devices**

a. Electrical devices which provide motor protection may be sensitive to current, temperature, or both.

b. Motor protection devices may be internal, built into the motor windings, or external, mounted on the surface of the motor.

c. Electrical devices used for motor protection include bimetal overloads, magnetic overloads, thermal overload relays, lockout relays, and solid-state motor protectors.

Note: Motor protection devices will be treated in depth in later units of this text.

13. **Bimetal protection devices**

a. Bimetal protection devices operate on the principle that an increase in temperature causes a bimetal strip or disc to warp.

b. The increase in temperature can be caused by excessive current passing through the bimetal, or the bimetal's proximity to high temperatures.

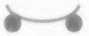
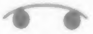
c. When the bimetal warps, it opens or closes a set or sets of contacts.

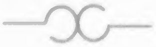
Information Sheet

d. Bimetal overloads may be line duty, in the line voltage circuit, or pilot duty, in the control circuit.

e. A bimetal protection device may be a manual reset overload or an automatic reset overload.

f. Two common uses of bimetal protection devices are as furnace limit switches and compressor overloads.

g. The symbol for a bimetal overload is:  or 

h. The symbol for a thermal overload is: .

14. Protecting electronic circuits

a. Electronic circuits are sensitive to things like transients, AC noise, and heat that usually do not bother regular, electrical circuits.

b. Electronic circuits, and especially integrated circuits, are extremely sensitive to instantaneous voltage surges called transients.

c. Variable resistors, called varistors, are used to protect electronic circuits from transients.

d. The resistance of the varistor is so high that current flows through the transformer or other loads, instead of the varistor, when normal voltage is applied.

e. Varistor resistance falls sharply during a voltage surge providing an alternate path, thus protecting a transformer and other loads from damage.

Note: In a normal resistor, resistance increases when voltage increases.

f. To avoid creating static electricity transients when handling PC boards:

(1) avoid touching component any more than necessary
(2) ground yourself before touching a PC board.
(3) keep yourself grounded, if possible, while handling electrostatic-sensitive components.

Note: Disposable grounding wrist straps are sometimes supplied with components.

(4) keep boards not in use in their original containers.

g. Use shielded cable when it is specified in the installation instructions; this protects electronic circuits from the effects of AC noise that may be riding on the DC control voltage.

h. Use of a heat sink such as finned aluminum around some components helps dissipate excessive heat which might otherwise damage the component.

Controls and Protection Devices
Unit 5

Job Sheet 1—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Shunt Circuits with One SPST Switch

Name______________________________ Attempt Number_____

Date ______________________________ Overall Rating ______

Evaluation Criteria	**Rating**
Number of pictorials completed	______
Number of working models fabricated to specifications	______
Number of ladder schematics completed	______

A. Tools and materials

ACR technician's hand tools
Fabrication/wiring board w/load selected by instructor
Conductors of various sizes
Fasteners as required
VOM or other test instrument
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Examine the graphics that follow on the following pages and then continue in order to complete a pictorial diagram of each circuit so you can follow your diagram to fabricate the circuit as a working model and test it to prove it meets specifications.

Note: Be sure to number the loads and switches.

☐ 3. After you fabricate and test the circuit, reference your working model and pictorial diagram as needed to draw a ladder schematic diagram to complete your work.

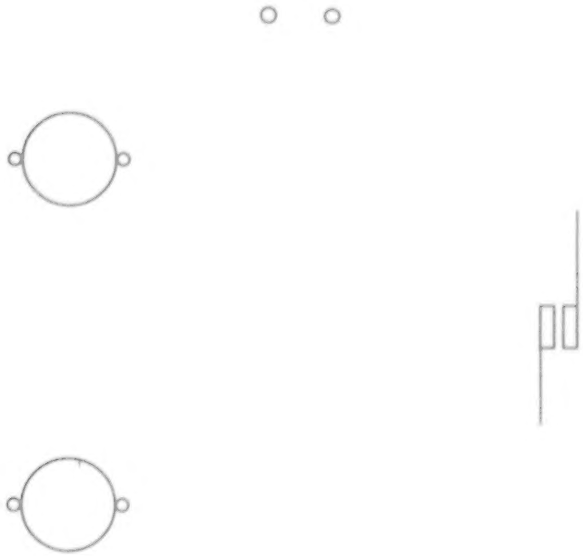
☐ 4. Follow all directions carefully; the pages are designed so that you can also reference your pictorial diagram to complete your ladder diagram.

☐ 5. Read all the instructions for each problem before you begin so you can ask your instructor for clarification of any part of the job sheet that you do not understand.

☐ 6. Examine the following graphic and draw a pictorial diagram to the following specifications: all loads controlled by one SPST switch and each load must have 60V when the switch is off, and when the switch is on, one of these loads will receive 120V and the other load receives 0V.

Note: This is a circuit used to obtain the harvest cycle in some Frigidaire ice makers, and it is used for other special ACR applications.

Problem A: Pictorial



☐ 7. Use your pictorial diagram as a guide for fabricating a circuit to use as a working model.

☐ 8. Test the circuit to prove it meets specifications.

☐ 9. Have your instructor check your work.

☐ 10. Reference your working model and pictorial diagram as needed to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 1

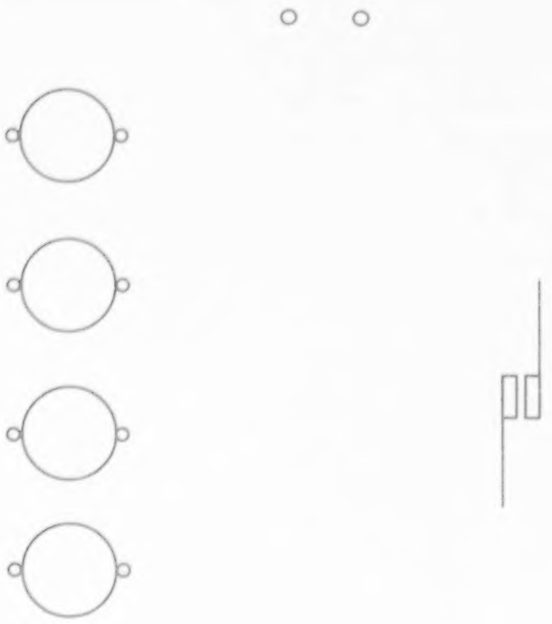
Problem A: Ladder Schematic

☐ 11. Have your instructor check your ladder schematic diagram.

☐ 12. Examine the following graphic and draw a pictorial diagram to the following specifications: all loads controlled by one SPST switch and all loads receive 30V each when the switch is off, but when the switch is on, two loads receive 60V each.

Note: This is a shunt that can "balance" or "unbalance" a number of loads for a variety of control functions.

Problem B: Pictorial



☐ 13. Use your pictorial diagram as a guide to fabricate a circuit to use as a working model.

☐ 14. Test your circuit to prove it meets specifications.

☐ 15. Have your instructor check your work.

☐ 16. Reference your working model and pictorial diagram as needed to complete a ladder diagram schematic in the space provided on the opposite page.

Job Sheet 1

Problem B: Ladder Schematic

☐ 17. Have your instructor check your ladder schematic diagram.

Comments ____

____

____

____

Controls and Protection Devices
Unit 5

Job Sheet 2—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Circuits with 3-Way Switches

Name______________________________ Attempt Number_____

Date ______________________________ Overall Rating ______

Evaluation Criteria	Rating
Number of pictorials completed	_____
Number of working models fabricated to specifications	_____
Number of ladder schematics completed	_____

A. Tools and materials

ACR technician's hand tools
Fabrication/wiring board w/loads selected by instructor
Conductors of various sizes
Fasteners as required
VOM or other test instrument
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Examine the graphics on the following pages and then continue in order to complete a pictorial diagram of each circuit so you can follow your diagram to fabricate a working model of the circuit and then test the circuit to prove it meets specifications.

Note: Be sure to number the loads and switches.

☐ 3. After you fabricate and test the circuit, reference your working model and pictorial diagram as needed to draw a ladder schematic diagram to complete your work, and be sure switches in the ladder schematic are in the same switch positions as in your pictorial.

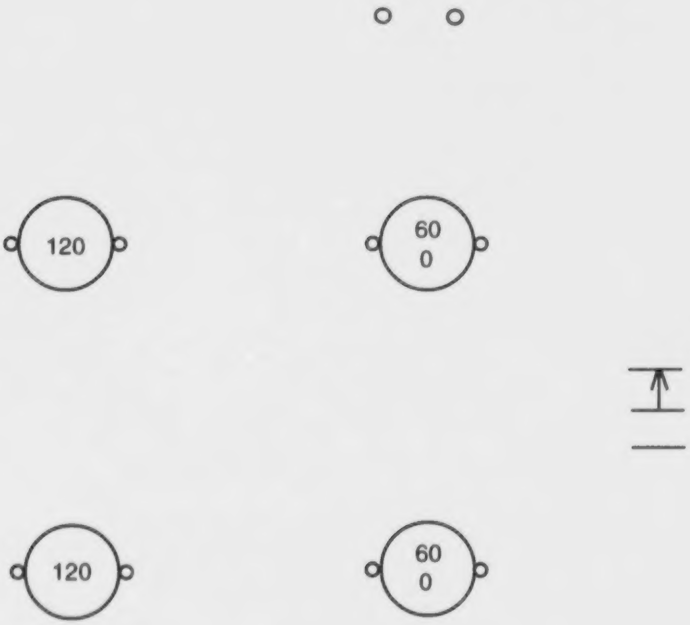
☐ 4. Follow all directions carefully; the pages are designed so that you can reference your pictorial diagram as you complete your ladder diagram.

☐ 5. Read all the instructions for each problem before you begin so you can ask your instructor for clarification of any part of the job sheet that you do not understand.

Job Sheet 2

☐ 6. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: with the switch "made" in one direction, two of the loads receive 60V each and the other two loads receive 0V each. When the switch is pushed to the opposite position, the two loads that received 60V will then receive 0V, and the two loads that received 0V will receive 120V.

Problem A: Pictorial



☐ 7. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 8. Test the circuit to prove it meets specifications.

☐ 9. Have your instructor check your work.

☐ 10. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

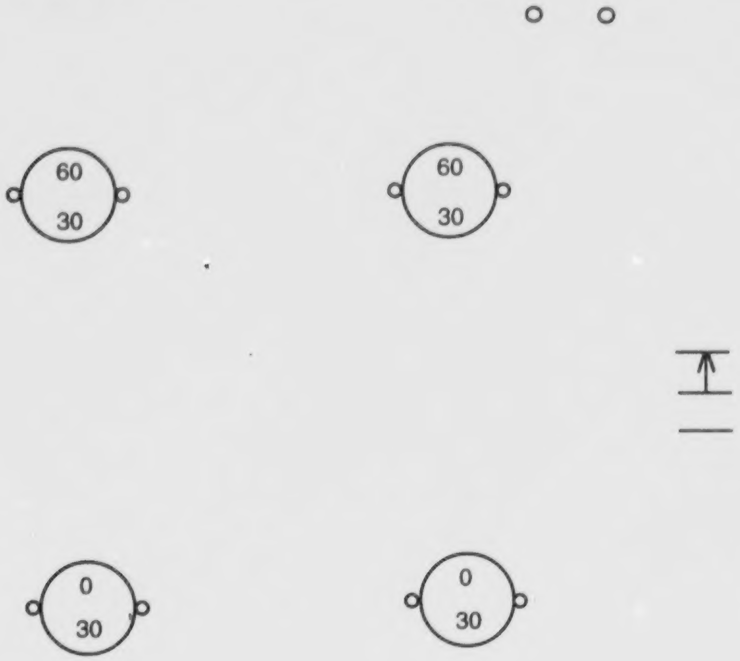
Problem A: Ladder Schematic

☐ 11. Have your instructor check your ladder schematic diagram.

Job Sheet 2

☐ 12. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: with the switch in one position, all loads receive 30V each. Place the switch in the opposite position and two of the loads receive 60V each and the other two loads receive 0V each.

Problem B: Pictorial



☐ 13. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 14. Test your circuit to prove it meets specifications.

☐ 15. Have your instructor check your work.

☐ 16. Use your working model and pictorial diagram as guides to complete a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

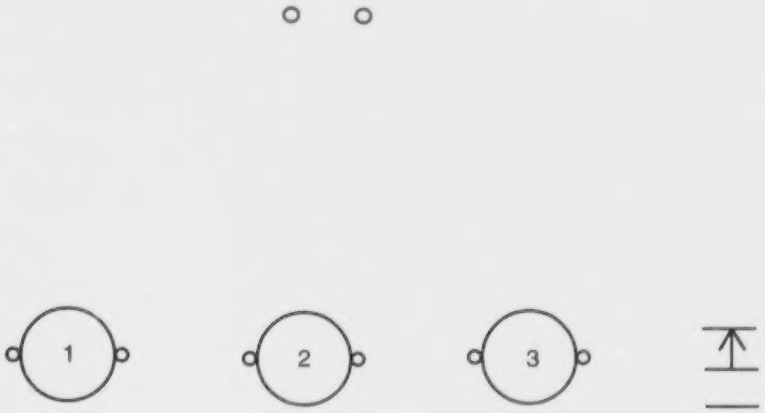
Problem B: Ladder Schematic

☐ 17. Have your instructor check your ladder schematic diagram.

Job Sheet 2

☐ 18. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: when the switch is "made" in one position, loads 1 and 2 receive 60V each, load 3 receives 0V. When the switch is "made" in the opposite position, load 2 and 3 receive 60V each and load 1 receives 0V.

Problem C: Pictorial



☐ 19. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 20. Test your circuit to prove it meets specifications.

☐ 21. Have your instructor check your work.

☐ 22. Use your working model and your pictorial as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

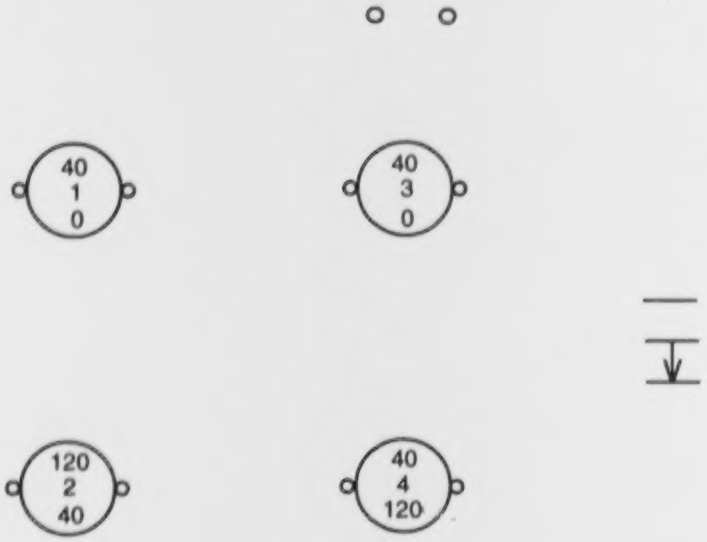
Problem C: Ladder Schematic

☐ 23. Have your instructor check your ladder schematic diagram.

Job Sheet 2

☐ 24. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: with the 3-way switch in one position, load 4 receives 120V and all other loads receive 40V each. With the 3-way switch in the opposite position, load 2 receives 120V and all other loads receive 40V each.

Problem D: Pictorial



☐ 25. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial diagram.

☐ 26. Test your circuit to prove that it meets specifications.

☐ 27. Have your instructor check your work.

☐ 28. Use your working model and your pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

Problem D: Ladder Schematic

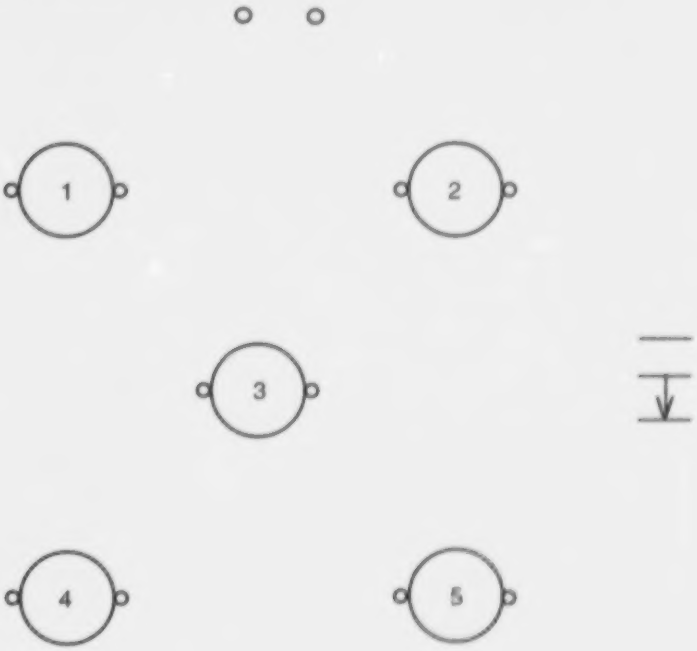
☐ 29. Have your instructor check your ladder schematic diagram.

Job Sheet 2

☐ 30. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: when the 3-way switch is in the down position, loads 4 and 5 receive 60V each and loads 1, 2, and 3 receive 40V each. When the 3-way switch is in the up position, loads 1 and 2 receive 60V each and loads 3, 4, and 5 receive 0V each.

Hint: In shunt circuits, a load does not have to be disconnected from power to be turned off. Refer to Objective 7 in your Information Sheet.

Problem E: Pictorial



☐ 31. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 32. Test your circuit to prove that it meets specifications.

☐ 33. Have your instructor check your work.

☐ 34. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

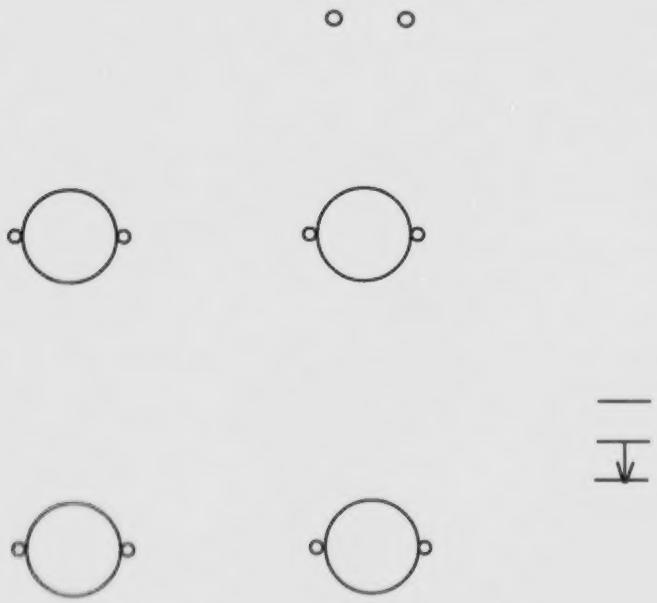
Problem E: Ladder Schematic

☐ 35. Have your instructor check your ladder schematic diagram.

Job Sheet 2

☐ 36. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: with the 3-way switch in one position, all loads receive 60V each. When the switch is placed in an opposite position, three of the loads receive 40V each and the remaining load receives 120V.

Problem F: Pictorial



☐ 37. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 38. Test your circuit to prove that it meets specifications.

☐ 39. Have your instructor check your work.

☐ 40. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

Problem F: Ladder Schematic

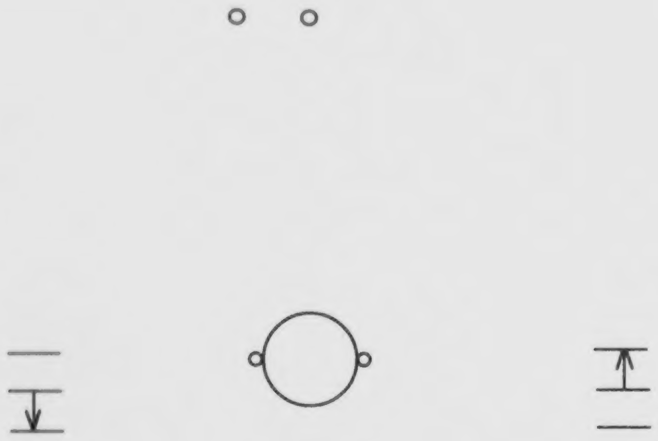
☐ 41. Have your instructor check your ladder schematic diagram.

Job Sheet 2

☐ 42. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: design the circuit so that either switch can "make" or "break" the load, and when load is on, either switch can turn the load off.

Hint: This circuit is typical of a household circuit where switches on opposite sides of a room control the same light.

Problem G: Pictorial



☐ 43. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 44. Test your circuit to prove it meets specifications.

☐ 45. Have your instructor check your work.

☐ 46. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

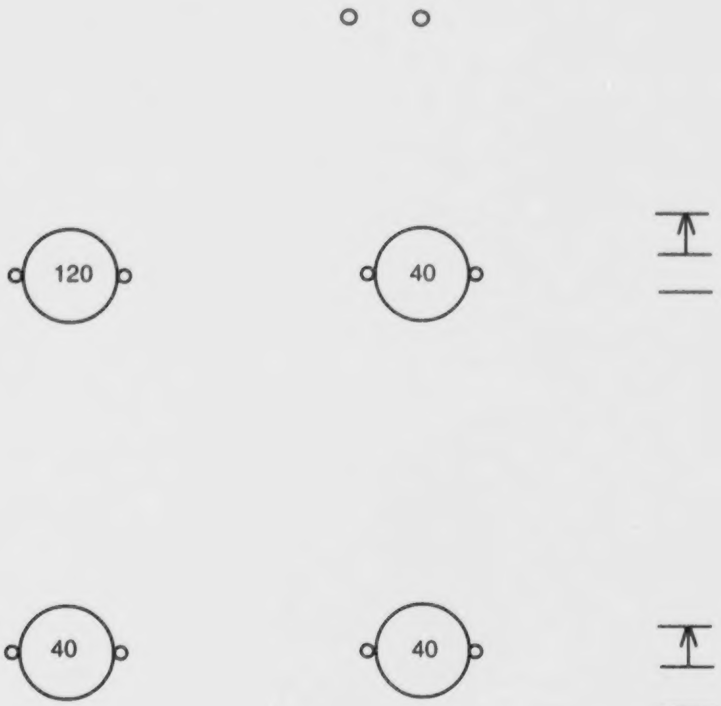
Problem G: Ladder Schematic

☐ 47. Have your instructor check your ladder schematic diagram.

Job Sheet 2

☐ 48. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: arrange loads so that each load gets its specified voltage requirement, and design the circuit so that either switch can "make" or "break" the circuit.

Problem H: Pictorial



☐ 49. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 50. Test your circuit to prove that it meets specifications.

☐ 51. Have your instructor check your work.

☐ 52. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 2

Problem H: Ladder Schematic

☐ 53. Have your instructor check your ladder schematic diagram.

Comments____

Controls and Protection Devices
Unit 5

Job Sheet 3—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Circuits With 3-Way and 4-Way Switches

Name____ Attempt Number_____

Date ____ Overall Rating ______

Evaluation Criteria	**Rating**
Number of pictorials completed	_____
Number of working models fabricated to specifications	_____
Number of ladder schematics completed	_____

A. Tools and materials

ACR technician's hand tools
Fabrication/wiring board w/load selected by instructor
Conductors of various sizes
Fasteners as required
VOM or other test instrument
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Examine the graphics that follow on the following pages and then continue in order to complete a pictorial diagram of each circuit so you can follow your diagram to fabricate the circuit as a working model and test it to prove it meets specifications.

Note: Be sure to number all loads and switches.

☐ 3. After you fabricate and test the circuit, reference your working model and pictorial diagram as needed to draw a ladder schematic diagram to complete your work.

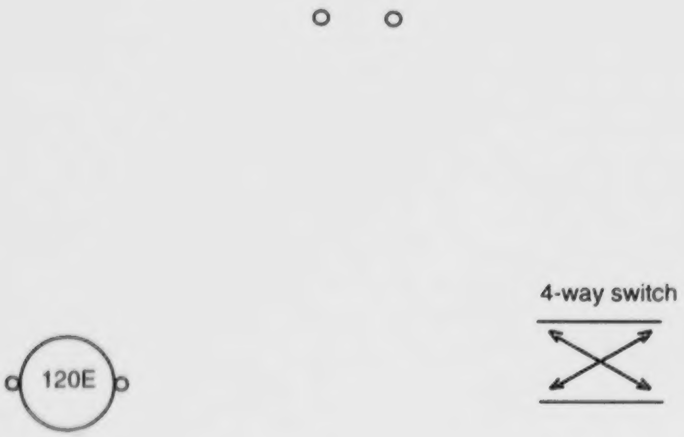
☐ 4. Follow all directions carefully; the pages are designed so that you can reference your pictorial diagram as you complete your ladder diagram.

☐ 5. Read all the instructions for each problem before you begin so you can ask your instructor for clarification of any part of the job sheet that you do not understand.

Job Sheet 3

☐ 6. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: in one position, the 4-way switch will energize the load and in the other position, the load will be off.

Problem A: Pictorial



☐ 7. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 8. Test your circuit to prove it meets specifications.

☐ 9. Have your instructor check your work.

☐ 10. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 3

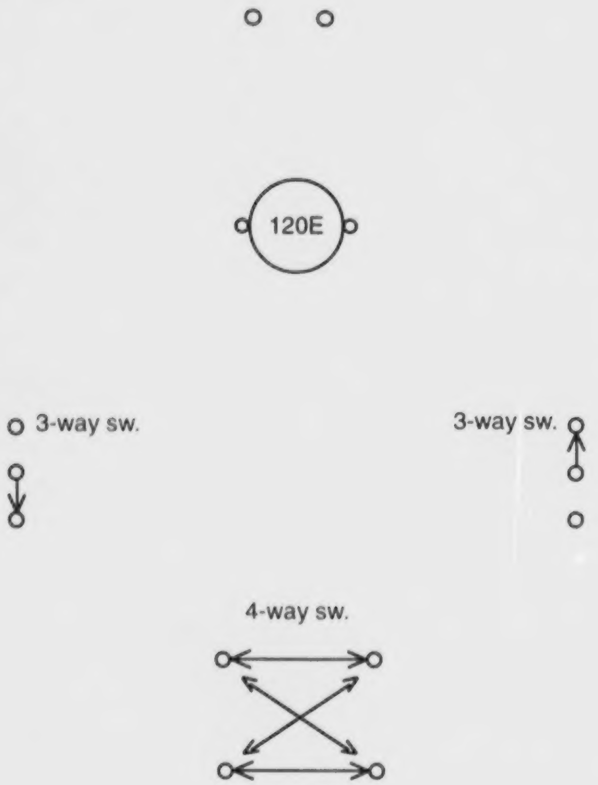
Problem A: Ladder Schematic

☐ 11. Have your instructor check your ladder schematic diagram.

Job Sheet 3

- ☐ 12. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: the load must be controlled from three locations. 3-way switches must be used at the ends and a 4-way switch must be used in the center, and any switch can be used to "make" or "break" the load.

Problem B: Pictorial



- ☐ 13. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.
- ☐ 14. Test your circuit to prove it meets specifications.
- ☐ 15. Have your instructor check your work.
- ☐ 16. Use your working model and pictorial diagram as guides to complete a ladder diagram schematic in the space provided on the opposite page.

Job Sheet 3

Problem B: Ladder Schematic

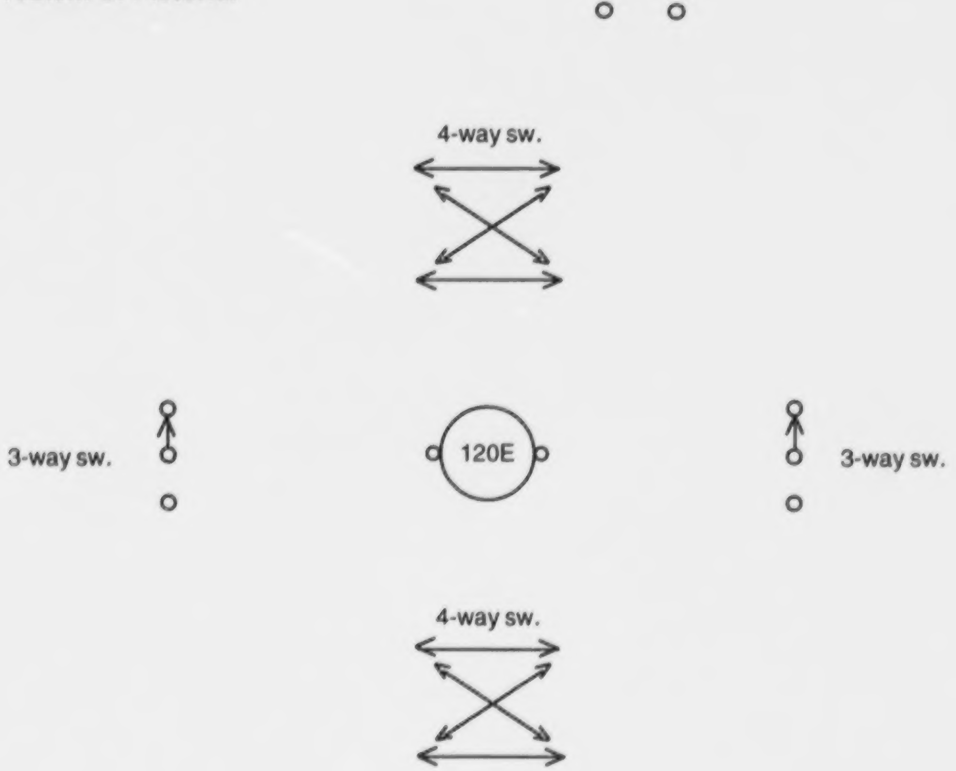
☐ 17. Have your instructor check your ladder schematic diagram.

Job Sheet 3

☐ 18. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: the load is controlled by 3-way switches at different locations, but two 4-way switches are also used. With any change of switch position, there should be a change of voltage to the load, whether it be 0V or 120V.

Note: This circuit is typical of lights in a multi-story apartment building stairway where all lights must be controllable from any apartment; only the top and bottom floors would have 3-way switches.

Problem C: Pictorial



☐ 19. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 20. Test your circuit to prove it meets specifications.

☐ 21. Have your instructor check your work.

☐ 22. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 3

Problem C: Ladder Schematic

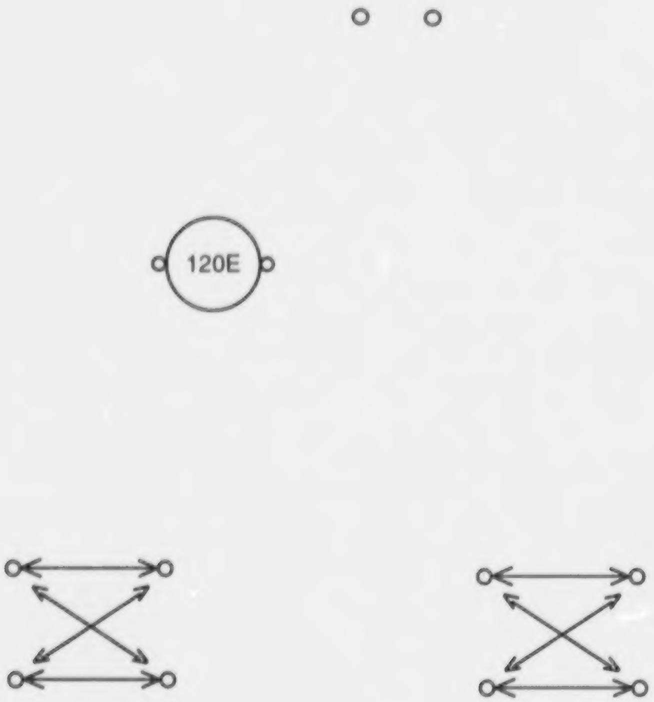
☐ 23. Have your instructor check your ladder schematic diagram.

Job Sheet 3

☐ 24. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: wire the 120V load so that either one of two 4-way switches will turn the load on or off.

Note: It is sometimes necessary to use 4-way switches in places where 3-way switches could also do the job.

Problem D: Pictorial



☐ 25. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 26. Test your circuit to prove it meets specfications.

☐ 27. Have your instructor check your work.

☐ 28. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 3

Problem D: Ladder Schematic

☐ 29. Have your instructor check your ladder schematic diagram.

Comments____

Controls and Protection Devices
Unit 5

Job Sheet 4—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Circuits With a Safety Switch

Name______________________________ Attempt Number_____

Date ______________________________ Overall Rating ______

Evaluation Criteria	**Rating**
Number of pictorials completed	_____
Number of working models fabricated to specifications	_____
Number of ladder schematics completed	_____

A. Tools and materials

ACR technician's hand tools
Fabrication/wiring board w/loads selected by instructor
Conductors of various sizes
Fasteners as required
VOM or other test instrument
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Examine the graphics on the following pages and then continue in order to complete a pictorial diagram of each circuit so you can follow your diagram to fabricate the circuit as a working model and test it to prove it meets specifications.

Note: Be sure to number loads and switches.

☐ 3. After you fabricate and test the circuit, reference your working model and pictorial diagram as needed to draw a ladder schematic diagram to complete your work.

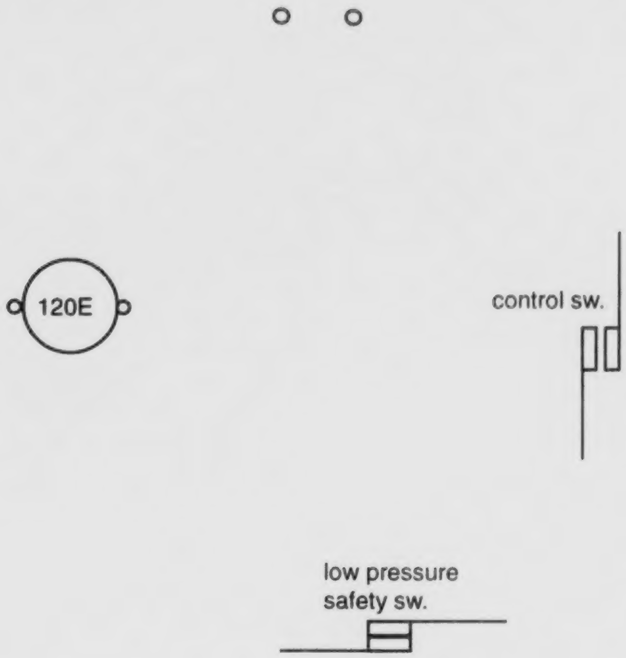
☐ 4. Follow all directions carefully; the pages are designed so that you can reference your pictorial diagram as you complete your ladder diagram.

☐ 5. Read all the instructions for each problem before you begin so you can ask your instructor for clarification of any part of the job sheet that you do not understand.

Job Sheet 4

☐ 6. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: wire the control switch and safety switch so that the circuit will demonstrate load safety protection.

Problem A: Pictorial



☐ 7. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

Note: You may have to substitute manual switches for some of the switches as you fabricate your working model, but be sure to use the proper symbols on your schematic as called for on your pictorial.

☐ 8. Test your circuit to prove it meets specifications.

☐ 9. Have your instructor check your work.

☐ 10. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 4

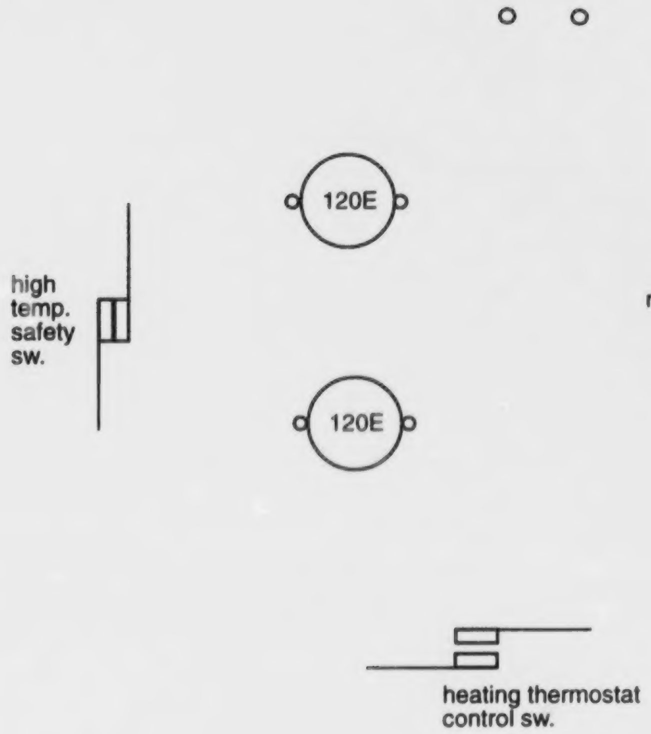
Problem A: Ladder Schematic

☐ 11. Have your instructor check your ladder schematic diagram.

Job Sheet 4

☐ 12. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: a master switch, a control switch, and a safety switch makes a circuit that demonstrates safety protection for two 120V loads.

Problem B: Pictorial



☐ 13. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

Note: You may have to substitute manual switches for some of the switches as you fabricate your working model, but be sure to use the proper symbols on your schematic as called for on your pictorial.

☐ 14. Test your circuit to prove it meets specifications.

☐ 15. Have your instructor check your work.

☐ 16. Use your working model and pictorial diagram as guides to complete a ladder diagram schematic in the space provided on the opposite page.

Job Sheet 4

Problem B: Ladder Schematic

☐ 17. Have your instructor check your ladder schematic diagram.

Comments____

____

____

____

Controls and Protection Devices
Unit 5

Job Sheet 5—Draw a Pictorial, Fabricate a Working Model, and Draw a Ladder Schematic of a Basic Refrigerator Circuit

Name____ Attempt Number_____

Date ____ Overall Rating ______

Evaluation Criteria	**Rating**
Pictorial completed properly	______
Working model fabricated properly	______
Ladder schematic completed properly	______

Tools and Materials

ACR technician's hand tools
Fabrication/wiring board w/designated components
Conductors of various sizes
Fasteners as required
VOM or other test instrument
Safety glasses

Procedure

☐ 1. Put on safety glasses.

☐ 2. Examine the graphic on the following page in order to complete a pictorial diagram of the circuit.

Note: This is a basic circuit used in many domestic refrigerators; it employs an electrical feature that seems to be contrary to good practice, and you will need to consider carefully how the conductor which is already included in the diagram affects the circuit.

☐ 3. Follow your diagram to fabricate the circuit as a working model, and test the working model to prove that it meets specifications.

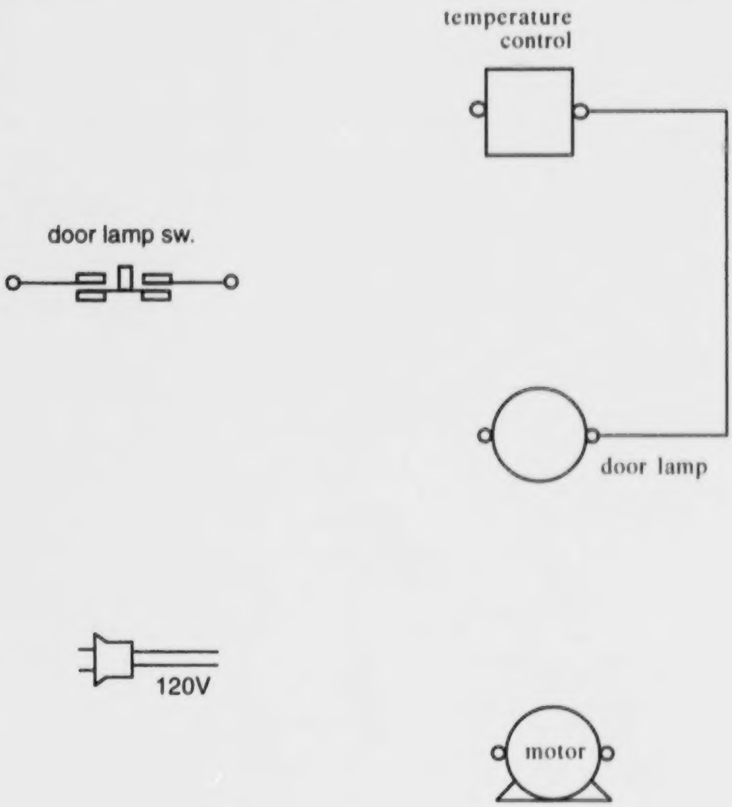
☐ 4. After you fabricate and test the circuit, reference your pictorial and working model as needed to draw a ladder schematic diagram of the circuit.

☐ 5. Read all the instructions carefully before you begin so you can ask your instructor for clarification of any part of the job sheet that you do not understand.

Job Sheet 5

☐ 6. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: the door lamp must light anytime the door switch is closed and the motor must be energized anytime the temperature control is made.

Pictorial



☐ 7. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 8. Test your circuit to prove it meets specifications.

☐ 9. Have your instructor check your work.

☐ 10. Use your working model and pictorial diagram as guides to complete a ladder schematic in the space provided on the opposite page.

Job Sheet 5

Ladder Schematic

☐ 11. Have your instructor check your ladder schematic.

☐ 12. Clean area and return tools and materials to proper storage.

Comments ____

Transformers and Relays

Unit 6

Objective Sheet

Unit Objective

After completing this unit, the student should be able to draw pictorials, fabricate working models, and draw ladder schematics for circuits with basic relays, circuits with dual relays, circuits with special applications, and circuits with multiple relays. The student should demonstrate these competencies by completing activities in the assignment and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to transformers and relays with their correct definitions.
2. Complete statements about how a transformer works.
3. Complete statements about control transformer specifications.
4. Complete statements about providing DC power.
5. Select true statements about relay components and uses.
6. Select true statements about using relay symbols in electrical drawings.
7. Solve problems about control relays and contactors.
8. Match control relays and contacts with their switching arrangements.
9. Select true statements about types of motor starting relays and their uses.
10. Complete statements about motor starting current relay operations.
11. Complete statements about motor starting current relay specifications.
12. Complete statements about motor starting voltage relay (potential relay) operations.

Objective Sheet

13. Select true statements about potential relay specifications.

14. Complete statements about time delay relays.

15. Select true statements about electronic controls for timed functions.

16. Identify selected relays. (Assignment Sheet 1)

17. Check current relays with an ohmmeter. (Job Sheet 1)

18. Check potential relays with an ohmmeter. (Job Sheet 2)

19. Check current relays with an ammeter and a voltmeter. (Job Sheet 3)

20. Check a potential relay with an ammeter and a voltmeter. (Job Sheet 4)

21. Install a solid-state, time-delay relay. (Job Sheet 5)

22. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with basic relays. (Job Sheet 6)

23. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with dual relays. (Job Sheet 7)

24. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with special applications. (Job Sheet 8)

25. Draw pictorials, fabricate working models, and draw ladder schematics for circuits with multiple relays. (Job Sheet 9)

Transformers and Relays
Unit 6

Information Sheet

1. **Terms and definitions**

   a. **Contactor**—A control relay rated at approximately 25A or higher which is usually energized by a control circuit, and which usually opens and closes a line voltage circuit

   b. **Control relay**—A relay that controls a line voltage load by means of control voltage

   c. **Control transformer**—A transformer used in a class 2 circuit

   d. **Control voltage (low voltage)**—5V to 30V used in control circuits which are referred to by the NEC as class 2 circuits

   e. **Line voltage**—Voltage supplied for use by residential and commercial consumers, usually 110V to 600V

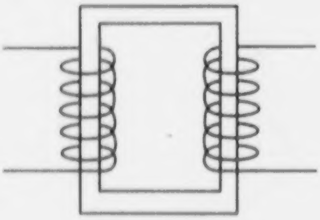
   Note: Utility companies refer to line voltage as low voltage in contrast to the 4,000V to 7,000V supplied to a supply transformer.

   f. **Relay**—An electromagnetic switch

   g. **UL (United Laboratories)**—A national organization dedicated to writing standards for the safe use and application of electrical materials and devices

2. **How a transformer works**

   a. A transformer is made by wrapping two wires close to each other around an iron core so that they form primary and secondary coils.

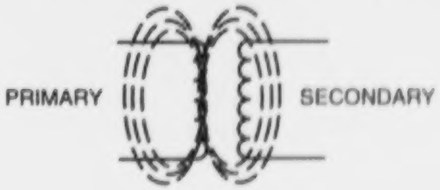


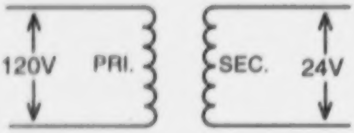
Iron Core

   b. When voltage flows through the primary coil, a magnetic field builds up around the primary coil.

Information Sheet

c. The arrangement of the coils causes most of the lines of force to cut across the secondary coil, and induce voltage in the secondary coil.





d. The amount of voltage induced in the secondary coil depends upon the ratio of the number of wraps in the primary coil to to the number of wraps in the secondary coil.

Example: A step-down transformer with a 5:1 (5 to 1) ratio means that if a primary coil with 5 wraps receives 120V, then the secondary coil would supply 24V because 120 divided by 5 is 24.

Note: The step-down transformer described in the above example is typical of an HVAC control transformer.

3. **Control transformer specifications**

a. The Primary Voltage and the Secondary Voltage ratings are stamped or printed on control transformers.

b. Another important transformer rating, stamped or printed on the transformer, is the VA rating which is the rated secondary voltage (V) times the maximum safe secondary load in amperes (A).

c. The VA rating determines the maximum current draw of the loads that can safely be connected to the secondary side of the transformer.

Example: Primary Voltage—120
Secondary Voltage—24
VA rating—40

For a transformer stamped with the above rating, the maximum safe secondary circuit current can be determined by dividing the VA rating by the secondary voltage rating. 40VA/24V = 1.67A.

d. Take care to select replacement transformers with the same voltage ratings as the original transformer, and within a VA rating equal to or greater than the VA rating of the original transformer.

Example: The transformer used as the example in item c could replace a transformer with a 25VA rating provided the voltage ratings were the same.

Information Sheet

e. NEC Class 2 transformers with a secondary voltage over 15V must have an internal fuse of 3.2A or less to meet UL requirements.

Example: The maximum VA rating that can be built into a transformer having 24V secondary voltage would therefore be 3.2A x 24V or 77VA.

4. Providing DC power

a. Since only AC voltage is available to power most ACR equipment, the low-level DC voltages necessary for electronic circuits are obtained by converting the available AC voltage to DC voltage.

b. Using diodes to convert AC voltage to DC voltage is called rectification.

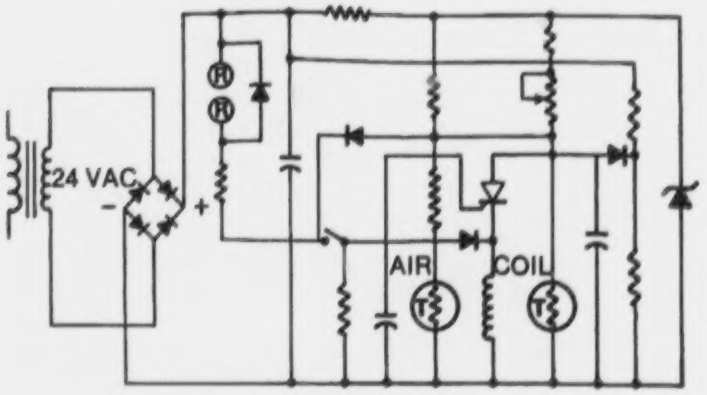
c. A center-tapped transformer, if needed, a rectifier, a filter, and a voltage regulator make up a DC power supply.

d. When you apply AC voltage to a diode, it will allow current flow only during the positive half-cycle of the AC.

e. If two diodes are placed in a circuit, the current will flow through one of the diodes during the positive half-cycle of the AC and flow through the other diode during the negative half-cycle of the AC.

f. The two diode configuration, known as a full-wave rectifier, produces continuous DC power, but requires a special center-tapped transformer; however, a type of full-wave rectifier called a bridge rectifier uses four diodes and does not require a special transformer.

Thermistor Application—Defrost Control



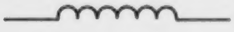
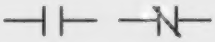
Information Sheet

g. A filter must be used with all full-wave rectifiers to smooth out the ouput and eliminate noise that can affect the operation of nearby appliances such as TVs.

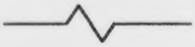
h. A voltage regulator is used to prevent fluctuations in the voltage when there are variations in the source voltage or the load circuit

5. **Relay components and uses**

   a. Most relays consist of a coil and one or more sets of contacts.

   Coil  **Contacts** 

   b. In most relays, when the coil is energized, it creates an electromagnet which attracts some type of iron lever which operates contacts.

   Magnetic coil 

   c. Relays use one circuit, usually a control circuit, to connect and disconnect another circuit.

   d. Relays are used for two major purposes, as control relays or motor starting relays.

6. **Using relay symbols in electrical drawings**

   a. Relay coils are loads and therefore are usually connected in a separate circuit on a pictorial diagram.

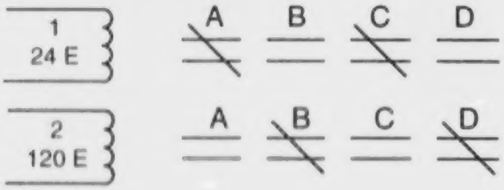
   b. Each relay coil will usually appear on a separate rung of a ladder schematic diagram.

   c. Relay contacts are placed in the circuit or on the rung with the load that they control which is not normally the same rung as the relay coil.

   d. When more than one relay is involved, each relay must be designated with a number, letter, or name.

   e. If a relay has more than one set of contacts, each set of contacts must be designated with a number or letter.

   f. Relay contacts on a drawing are usually lettered or numbered in order from the coil outward.



Information Sheet

7. Control relays and contactors

a. Control relays and contactors are set apart only by their amperage ratings; up to 25A the device is called a relay and above 30A, the device is called a contactor, and the range from 25A to 30A may be called either.

b. Control relays may use low voltage to control low voltage or low voltage to control line voltage.

c. Contactors nearly always use low voltage to control line voltage.

d. Using low voltage control circuits to operate relays makes it easier to control high amperage line voltage loads from a remote location because this enables installers to use smaller wires which are not subject to as many code requirements.

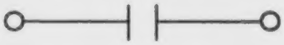
Example: For room thermostats in residences, wiring does not have to be in conduit nor installed by a licensed electrician.

e. Specifications to be considered when replacing a control relay or contactor include:

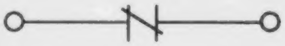
(1) original part number.
(2) physical dimensions of original and replacement.
(3) coil voltage.
(4) number of poles.
(5) switch or contact arrangements.
(6) full load amperage of load(s) being controlled.
(7) locked rotor amperage of load(s) being controlled.

8. Control relay and contactor switching arrangements

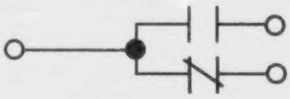
a. Single pole single throw, normally open, SPST NO.



b. Single pole single throw, normally closed, SPST NC.

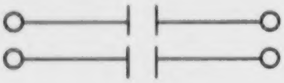


c. Single pole double throw, SPDT.

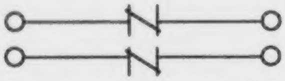


Information Sheet

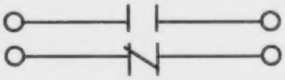
d. Double pole single throw, normally open, DPST NO.



e. Double pole single throw, normally closed, DPST NC.



f. Double pole single throw, normally closed and normally open, DPST NC and NO.



9. **Types of motor starting relays and their uses**

   a. Many hermetic motors require the starting assistance of a start winding and/or start capacitor which must be disconnected after the motor starts, and the disconnect is accomplished by a relay called a motor starting relay.

   b. The name "motor starting relay" refers to when the relay is used and not what it is used for; motor starting relays do not start motors, they only disconnect the starting components after the motor starts.

   c. Hermetic compressor motors require an external starting device because the electric components are exposed to refrigerant and oil in the system and internal electrical devices could cause dangerous sparks or arcing.

   d. Motor starting relays respond either to current or voltage.

   e. Current relays include both the coil-type and hot wire-types and are used on many domestic refrigerator and freezer compressors.

   f. Voltage relays are referred to as potential relays and are used on air conditioning and commercial refrigeration compressors.

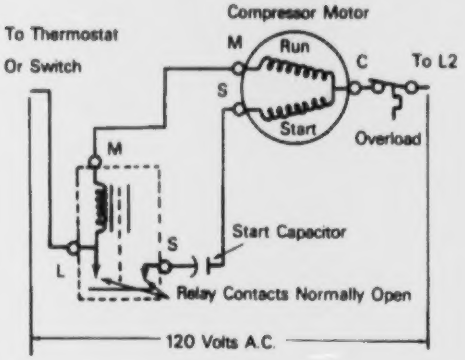
   g. Solid-state replacements are available for all current relays and many potential relays.

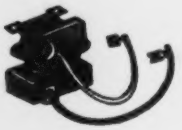
Information Sheet

10. **Motor starting current relay operations**

    a. Current relays respond to the amperage draw of the run windings of a compressor motor.

    b. Coil-type current relays have normally open contacts in the start winding circuit which close in response to the high starting amperage and open when amperage drops to the lower running amperage.

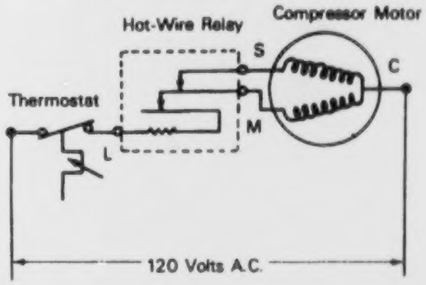

Compressor Motor
To Thermostat
Or Switch
M
Run
C
To L2
S
Start
Overload
M
Start Capacitor
S
L
Relay Contacts Normally Open
120 Volts A.C.

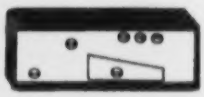


    c. Coil-type current relays are usually positional, meaning that they have to be physically installed as installation arrows or labels indicate.

    d. Hot-wire type current relays have normally closed contacts in the start winding circuit which open in response to the continuous running amperage of a compressor motor.

    e. Hot-wire type current relays also function as overloads since they have normally closed contacts in the run winding circuit which open if excessive amperage continues longer than a few seconds.

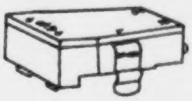

Hot-Wire Relay
Compressor Motor
S
C
Thermostat
M
L
120 Volts A.C.



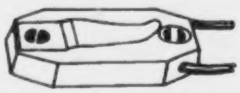
Information Sheet

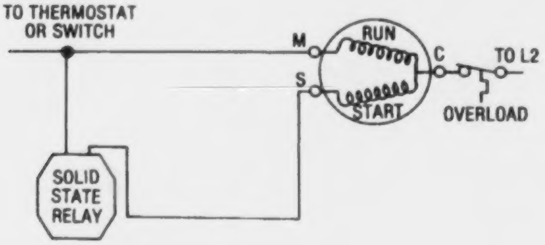
f. Solid-state replacements for current relays can be used to replace hundreds of different relays and they operate just like the originals.

Push-on solid-state relay



Snap-on solid-state relay





11. **Motor starting current relay specifications**

a. Terminal L connects to line voltage.

b. Terminal M connects to the motor run winding.

Note: Some OEMs may mark the M terminal with an R.

c. Terminal S connects to the motor start winding.

Note: Some OEMS may mark the S terminal with a P to indicate phase winding or sometimes with an A to indicate auxiliary winding.

d. Terminal designations 1, 2, and 3 may be used instead of L, M, and S.

e. Replacement relay specifications include:

(1) equipment model and serial number.

(2) compressor motor model number.

(3) compressor motor horsepower.

(4) compressor motor amperage.

(5) original relay part number.

(6) voltage.

(7) position, if positional.

Information Sheet

12. Motor starting voltage relay (potential relay) operations

a. A potential relay is a motor starting relay that operates by reacting to changes in the back EMF generated in the start winding.

b. Potential relays have several voltage ratings, line voltage, constant-coil voltage, pick-up voltage, and drop out voltage.

c. Line voltage is the source voltage being applied to the motor.

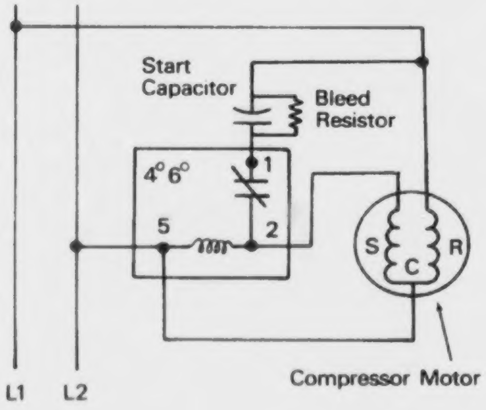
d. Constant-coil or continuous voltage is the back EMF generated in the compressor motor start windings.

e. Pick-up voltage is the minimum and maximum voltages at which the relay will energize.

f. The drop out voltage is the minimum and maximum voltages at which the relay will deenergize.

g. Back EMF increases across the start windings as the motor picks up speed; at approximately 75% of operating speed, pick-up voltage is reached, the potential relay is energized, and the relay contacts disconnect the start components.

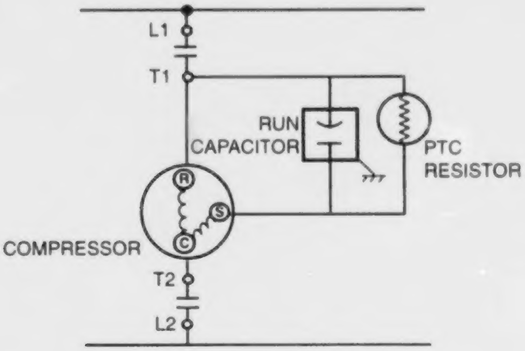
h. Back EMF decreases as the motor slows down; at approximately 25% of operating speed, voltage decreases to drop out voltage, the potential relay is deenergized, and the relay contacts reconnect the start components.



i. A solid state hard start assist device can be used in place of a potential relay and start capacitor when minimal start assist is required.

Information Sheet

j. The solid state device is a PTC (positive temperature coefficient) resistor which is usually simple to install at the run capacitor terminals.



13. Potential relay specifications

a. Terminal #1 connects to the start capacitor.

b. Terminal #2 connects to the motor start winding or the other end of the wire going to the start terminal.

c. Terminal #5 connects to the motor common terminal or the other end of the wire going to the common terminal.

d. Terminals #3, #4, and #6 are simply points for wire connections and are not connected to internal working components of the relay.

e. Replacement relay specifications may include:

(1) Equipment model and serial number.
(2) Compressor motor model number.
(3) Compressor motor horsepower.
(4) Original relay part number.
(5) Line voltage, constant-coil voltage, pick-up voltage, and drop out voltage.

14. Time delay relays

a. Time delay relays delay or sequence the energizing of loads such as sequencing electric furnace heating elements or delaying the restart of an air conditioner compressor.

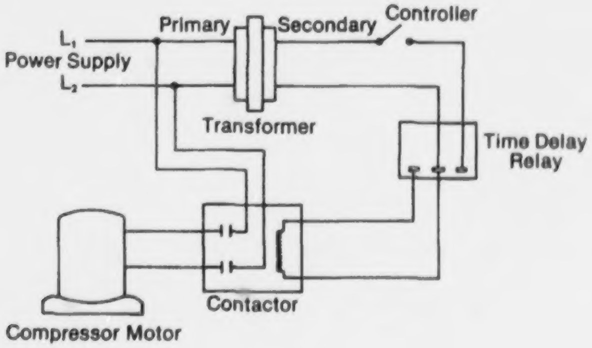
b. Time delay relays may be low or line voltage energized, and may operate line or low voltage devices to accomplish their purposes.

c. Check specifications carefully when installing a time delay relay to avoid mixing up the high and low voltage connections.

Information Sheet

d. Time delay relays may be actuated by solid-state components, a motorized cam or a thermal warp switch which is usually a bimetal device.

e. Solid-state time delay relays are popular for preventing compressor short cycling.



15. **Electronic controls for timed functions**

a. Many electromechanical components used for timed functions are being replaced by electronic versions.

b. Electronic versions are simpler, more reliable, and easier for a technician to troubleshoot.

c. The electronic version is packaged on a single PC board or sealed electronic module which must be replaced if it is receiving the correct input signals, but is not delivering the correct output signals to loads it controls.

d. Electronic time delays will usually have a feature that allows a service technician to bypass the time delay by placing a jumper across designated terminals on the board.

Note: The bypass feature allows a technician to test a circuit without waiting for the time delay.

e. Examples of electronic controls used for timed functions include:

(1) setback thermostats.

(2) compressor start delays.

(3) fan start delays.

(4) fan shut-off delays.

(5) defrost controls.

Unit 6

Assignment Sheet 1—Identify Selected Relays

Name______________________________________Overall Rating________________

Evaluation Criteria	**Rating**
Number of relay groups properly identified	_____
Number of relay types properly identified	_____

Directions: Your instructor has selected an assortment of relays used in ACR applications. Each relay is tagged with a number. Identify each relay by its group name and when applicable, specific type.

Examples:
1. Motor starting current relay, hot-wire.
2. Control relay, low-voltage.

Relay 1 (group):______________________________________ Type:______________

Relay 2 (group):______________________________________ Type:______________

Relay 3 (group):______________________________________ Type:______________

Relay 4 (group):______________________________________ Type:______________

Relay 5 (group):______________________________________ Type:______________

Relay 6 (group):______________________________________ Type:______________

Relay 7 (group):______________________________________ Type:______________

Relay 8 (group):______________________________________ Type:______________

Relay 9 (group):______________________________________ Type:______________

Relay 10 (group):_____________________________________ Type:______________

Note: If your instructor has selected more than 10 relays, complete your assignment on the back of this page.

Transformers and Relays
Unit 6

Job Sheet 1—Check Current Relays with an Ohmmeter

Name____________________________________Attempt Number______
Date____________________________________Overall Rating_______

Evaluation Criteria	**Rating**
Relays checked upright at L and M terminals	_____
Relays checked upright at M and S terminals	_____
Relays checked upside down at M and S terminals	_____

Tools and materials

Positional current relays (coil type) as selected by instructor
Ohmmeter

Procedure:

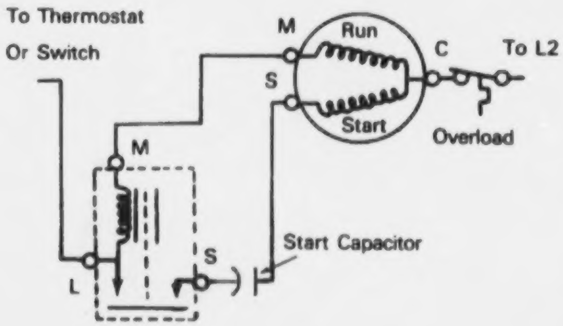
> **Caution:** All power must be removed from a relay before checking it with an ohmmeter.

☐ 1. Put on safety glasses.

☐ 2. Zero ohmmeter on R x 1 scale if it is an analog meter.

☐ 3. Identify L, M, and S terminals as you check each current relay; if terminals are not marked on the relay, use the following diagram to assist with proper identification before you remove the relay, and check with your instructor if you have a problem.

Note: Even though a relay is not connected to power, you can get misleading readings if the relay is still connected to other components.



Job Sheet 1

☐ 4. Place ohmmeter leads on L and M terminals of the current relay.

☐ 5. Hold relay in upright position; be sure you have properly identified the top of the relay.

☐ 6. Record your ohmmeter readings here:

Current relay 1_____
Current relay 2_____

☐ 7. Evaluate the relays according to the following: if the ohmmeter reads approximately 1Ω, the relay coil is okay, but if it reads ∞, the relay coil is open.

Current relay 1________
Current relay 2________

☐ 8. Move ohmmeter lead from L to S on relay so that your leads touch the M and S terminals.

☐ 9. Evaluate the relays according to the following: if the ohmmeter reads ∞, the relay contacts are open as they should be, but if the relay has a low resistance reading, the contacts are stuck closed.

☐ 10. Record your readings and evaluations in the spaces provided:

Reading	Evalution
Current Relay 1_____	___________
Current Relay 2_____	___________

☐ 11. Turn the relay upside down and touch leads again to the M and S terminals.

☐ 12. Evaluate the relays according to the following: if the ohmmeter has low resistance reading, the contacts are okay, but if the reading is ∞ or high resistance, the contacts are not closing properly.

Job Sheet 1

☐ 13. Record your readings and evaluation in the spaces provided:

Reading	Evaluation
Current Relay 1_____	____________
Current Relay 2_____	____________

☐ 14. Have your instructor evaluate your findings.

☐ 15. Clean up area and return tools and materials to proper storage.

Comments ____
____
____

Transformers and Relays
Unit 6

Job Sheet 2—Check Potential Relays with an Ohmmeter

Name____Attempt Number______

Date____Overall Rating_______

Evaluation Criteria	**Rating**
Ohm check properly made at terminals 1 and 2	_____
Ohm check properly made at terminals 1 and 5	_____
Evaluations recorded for all selected relays	_____

Tools and materials

Potential relays as selected by instructor
Ohmmeter

Procedure

> **Caution**: All power must be removed from a relay before checking it with an ohmmeter.

☐ 1. Put on safety glasses.

☐ 2. Zero ohmmeter on R x 1 scale, if it is an analog meter.

☐ 3. Make sure all wiring has been disconnected from each relay before you check it.

Note: Even though a relay is not connected to power, you can get misleading readings if the relay is still connected to other components.

☐ 4. Identify terminals 1, 2, and 5 on the relay.

☐ 5. Place ohmmeter leads on terminals 1 and 2 of the relay.

☐ 6. Evaluate the relay contacts according to the following: if the ohmmeter reads infinity or high resistance, this indicates open or dirty relay contacts, but if there is a zero or near zero ohm reading, the contacts are properly closed.

Job Sheet 2

☐ 7. Record your readings and evaluations in the spaces provided.

Reading	Evaluation
Relay 1_____	__________
Relay 2_____	__________

Note: If your instructor has selected more than two relays, complete your recordings at the end of this job sheet.

☐ 8. Place ohmmeter leads on terminals 1 and 5 of the relay.

☐ 9. Evaluate the relay coil according to the following: if the ohmmeter reads approximately 800 to 1200 ohms, the coil is okay; a resistance lower or higher usually means the relay coil is shorted or open.

☐10. Record your readings and evaluations in the spaces provided.

Reading	Evaluation
Relay 1_____	__________
Relay 2_____	__________

☐11. Have your instructor check your readings and evaluations.

☐12. Clean up area and return tools and materials to proper storage.

Comments

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Transformers and Relays
Unit 6

Job Sheet 3—Check Current Relays With an Ammeter and a Voltmeter

Name____Attempt Number______
Date____Overall Rating_______

Evaluation Criteria	**Rating**
Coil-type relay properly checked	______
Hot-wire relay properly checked	______
Solid-state relay properly checked	______

Tools and materials

Small hermetic refrigeration trainer(s) or system(s) with coil-type current relay, hot-wire type current relay, and solid-state current relay as selected by instructor
ACR technician's hand tools
Voltmeter and clamp-on ammeter
Safety glasses

Procedure

☐ 1. Put on safety glasses.

☐ 2. Make sure electrical power is disconnected from the system.

☐ 3. Perform the following procedure on a system with each type of relay listed in tools and materials.

☐ 4. Check relay specifications and horsepower and electrical ratings of the compressor motor, and record the necessary information below:

____
____

☐ 5. On each relay, clamp the ammeter around the wire connected to the S terminal, if the wire to the S terminal is accessible.

☐ 6. Start the system and read amperage draw for each type of relay.

☐ 7. Evaluate the relay according to the following: if the ammeter reads momentary amp draw and then drops to zero, the relay is operating properly; if the amperage draw does not drop to zero after about 10 seconds, disconnect the relay and check for stuck contacts with an ohmmeter.

Job Sheet 3

☐ 8. Record your evaluations:

Coil-type____________________

Hot-wire type____________________

Solid-state____________________

☐ 9. Turn the system off.

☐ 10. Select an AC range which will allow a reading in the center one-third of the scale on the voltmeter.

☐ 11. Place voltmeter leads on L and S terminals on each current relay, if the terminals are accessible.

☐ 12. Start the system and read the voltmeter.

☐ 13. Evaluate your reading according to the following: if you get a momentary voltage reading and then it drops to zero, the relay is working properly; if voltage reading continues for longer than 10 seconds, remove the relay and check for stuck relay contacts.

Note: In the field, a service technician would normally use either the amperage check or the voltage check, but not both.

☐ 14. Record your evaluations:

Coil-type ____________________

Hot-wire type ____________________

Solid-state ____________________

☐ 15. Clamp ammeter around the wire connected to the L terminal for each relay and read compressor run amps.

☐16. Record your readings and compare with compressor FLA:

Coil-type ________ FLA ________

Hot-wire ________ FLA ________

Solid-state ________ FLA ________

☐ 17. Have your instructor check your findings.

☐ 18. Clean up area and return tools and materials to proper storage.

Comments: ____________________

____

____

Transformers and Relays
Unit 6

Job Sheet 4—Check a Potential Relay With an Ammeter and a Voltmeter

Name____Attempt Number______
Date____Overall Rating______

Evaluation Criteria	Rating
Check made for stuck contacts	_____
Check made for properly opening contacts	_____
Check made to evaluate back EFM	_____

Tools and Materials

Refrigeration trainer or system
 with potential relay
ACR technician's hand tools
Ammeter and voltmeter
Safety glasses

Procedure

☐ 1. Put on safety glasses.

☐ 2. Record relay specifications and compressor motor horsepower and electrical ratings:

____
____

☐ 3. Select a scale on the ammeter that will read approximately double the FLA of the compressor.

☐ 4. Clamp the ammeter around the wire from terminal 2 on the potential relay.

☐ 5. Start the system and read amperage draw.

☐ 6. Evaluate your readings according to the following: if you read momentary amps and then a drop to near zero, the relay is operating properly; if the amperage draw does not drop after about 10 seconds, remove the relay and check for stuck contacts.

☐ 7. Record your evaluation:

____
____
____

Job Sheet 4

☐ 8. Have your instructor check your findings.

☐ 9. Turn off the system.

☐ 10. Select the highest AC range on the voltmeter.

☐ 11. Place voltmeter leads on terminals 1 and 2 of the relay.

☐ 12. Start the system and read the voltmeter.

☐ 13. Evaluate the relay according to the following: if the voltmeter reads zero volts at the instant of start, and then reads line voltage or more after the compressor motor reaches approximately 75% of its running speed, the contacts are opening as they should; if voltage continues to read zero after compressor motor starts, the contacts are not opening, so stop the system immediately!

☐ 14. Place voltmeter leads on terminals 2 and 5 of the relay and read the back EMF.

☐ 15. Record your evaluation and back EMF reading:

____

____

☐ 16. Turn off the system.

☐ 17. Have your instuctor check your findings.

☐ 18. Clean up area and return tools and materials to proper storage.

Comments: ____________________________________

____

____

Transformers and Relays
Unit 6

Job Sheet 5—Install a Solid State, Time-Delay Relay

Name____Attempt Number______
Date____Overall Rating_______

Evaluation Criteria	Rating
Solid-state relay installed per instructions	_____
System operation verified	_____

A. Tools and materials

Residential air conditioning system or trainer
with 24V contactor
ACR technician's handtools
VOM
Solid-state time delay relay
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Make sure electrical power is disconnected from the system.

☐ 3. Read directions included on or accompanying the relay.

☐ 4. Remove control box cover or covers as needed.

☐ 5. Disconnect 24V control wires going to the contactor.

☐ 6. Locate a convenient spot inside the control box, if possible, to mount the relay.

☐ 7. Mount the relay with screws, peel-and-stick adhesive patch, or other fasteners as needed.

☐ 8. Connect control wires and wires going to the contactor to the time delay relay as shown in the directions that accompany the relay; the diagram accompanying this job sheet presents a typical installation.

☐ 9. Reconnect power, start the system, and record the length of time it takes for the system to start: _________________.

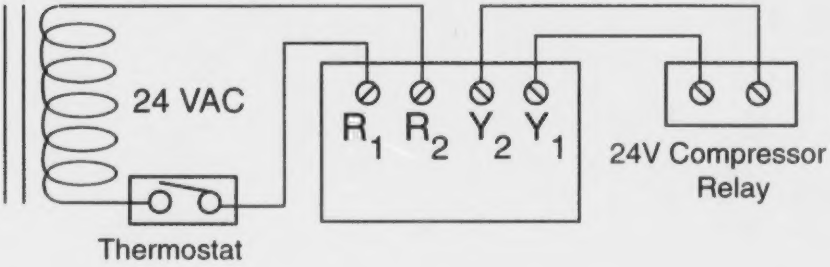
Job Sheet 5

☐ 10. Use the thermostat to stop and restart the system, and record the length of time it takes for the system to restart: ________________.

☐ 11. Have your instructor check your installation and results.

☐ 12. Turn system off, clean up area, and return tools and materials to proper storage.

Typical Diagram for Installation


24 VAC
R1
R2
Y2
Y1
24V Compressor Relay
Thermostat

Comments: ____

____

____

Transformers and Relays
Unit 6

Job Sheet 6—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Circuits With Basic Relays

Name____________________________________ Attempt Number______
Date____________________________________ Overall Rating_______

Evaluation Criteria	**Rating**
Number of pictorials completed	_____
Number of ladder schematics completed	_____
Number of working models fabricated to specifications	_____

A. Tools and materials

ACR technician's hand tools
Fabrication/wiring board
Power supply
Conductors of various sizes
Loads as selected by instructor
Fasteners as required
VOM or other test instrument
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Examine the graphics on the following pages and then continue in order to complete a pictorial diagram of each circuit so you can follow your diagram to fabricate the circuit as a working model and test it to prove it meets specifications.

☐ 3. After you fabricate and test the circuit, reference your working model and pictorial diagram as needed to draw a ladder schematic diagram to complete your work.

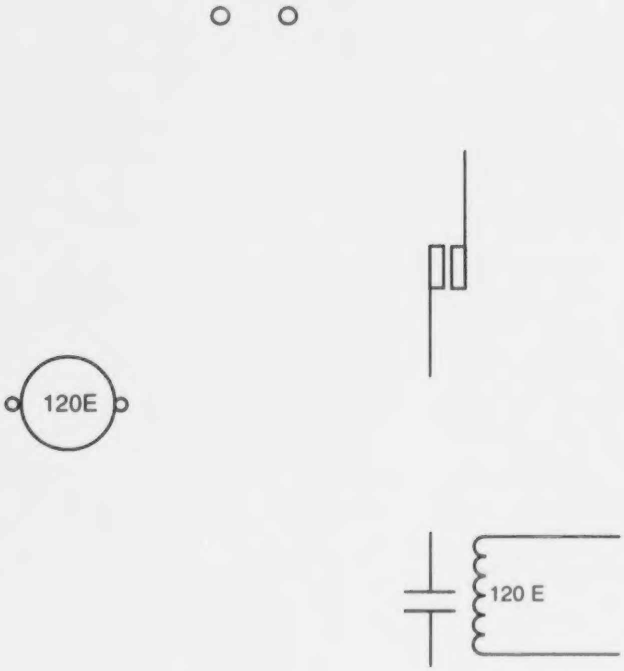
☐ 4. Follow all directions carefully; the pages are designed so that you can reference your pictorial diagram as you complete your ladder diagram.

☐ 5. Number loads and switches as needed, and read all the instructions before you begin so you can ask your instructor for clarification of any part of the job sheet that you do not understand.

Job Sheet 6

☐ 6. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: one SPST switch which energizes a 120V relay which in turn provides voltage to the load.

Problem A: Pictorial



☐ 7. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 8. Test your circuit to prove it meets specifications.

☐ 9. Have your instructor check your work.

☐10. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 6

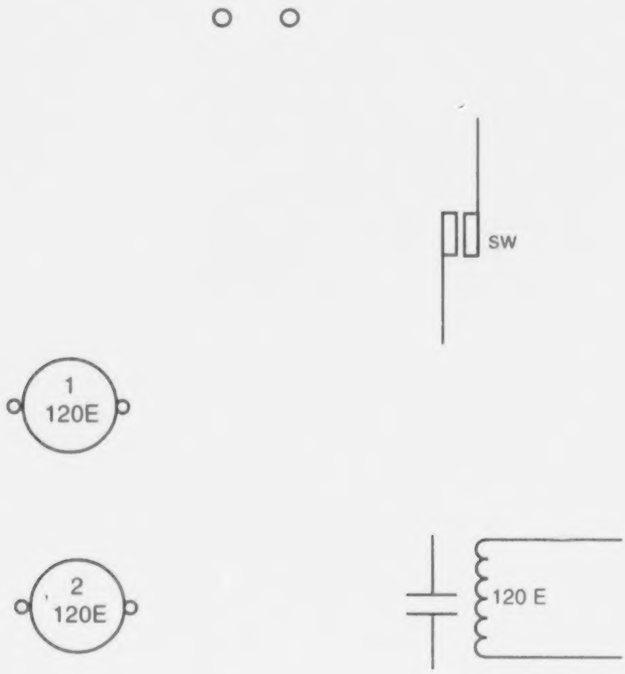
Problem A: Ladder Schematic

☐ 11. Have your instructor check your ladder schematic diagram.

Job Sheet 6

☐ 12. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: one SPST switch supplies voltage to the relay coil, and each load must receive 120V through the relay contacts.

Problem B: Pictorial



☐ 13. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 14. Test your circuit to prove it meets specifications.

☐ 15. Have your instructor check your work.

☐ 16. Use your working model and pictorial diagram as guides to complete a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 6

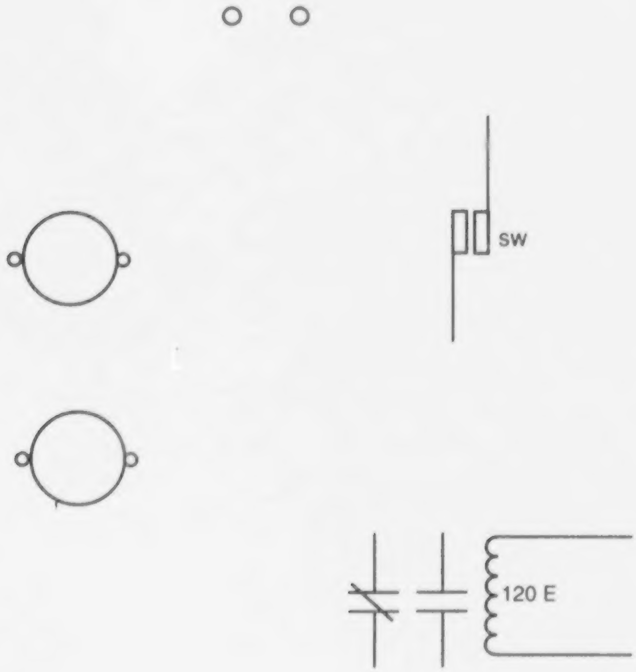
Problem B: Ladder Schematic

☐ 17. Have your instructor check your ladder schematic diagram.

Job Sheet 6

☐ 18. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: one SPST switch supplies voltage to a 120V relay. With the switch off, one load receives voltage through the relay, but the other load will have no voltage. With the switch on, the two loads will change their voltages inversely; in other words, the first load will have no voltage and the second load will receive voltage through the relay.

Problem C: Pictorial



☐ 19. Use your pictorial as a guide to fabricate a working model of the circuit in your pictorial.

☐ 20. Test your circuit to prove it meets specifications.

☐ 21. Have your instructor check your work.

☐ 22. Use your working model and pictorial diagram as guides to completed a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 6

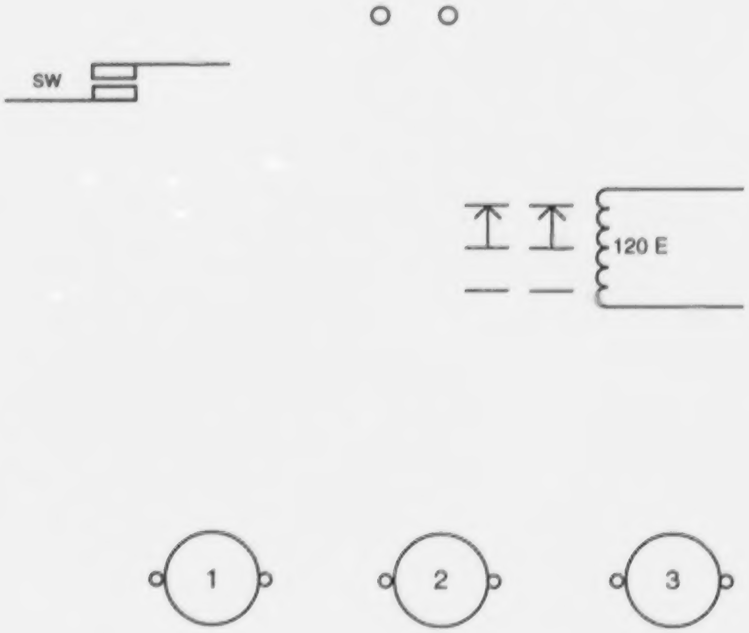
Problem C: Ladder schematic

☐ 23. Have your instructor check your ladder schematic diagram.

Job Sheet 6

☐ 24. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: switch 1 makes the relay which sends 40V to all loads. With the switch off, loads 1 and 2 receive 60V and load 3 receives 0V.

Problem D: Pictorial



☐ 25. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 26. Test your circuit to prove it meets specifications.

☐ 27. Have your instructor check your work.

☐ 28. Use your working model and pictorial diagram as a guide to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 6

Problem D: Ladder Schematic

☐ 29. Have your instructor check your ladder schematic diagram.

Comments ____

____

____

Transformers and Relays
Unit 6

Job Sheet 7—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Circuits With Dual Relays

Name______________________________Attempt Number______
Date______________________________Overall Rating______

Evaluation Criteria	**Rating**
Number of pictorials completed	______
Number of ladder schematics completed	______
Number of working models fabricated to specifications	______

A. Tools and materials

ACR technician's hand tools
Fabrication/wiring board
Power supply
Conductors of various sizes
Loads as selected by instructor
Fasteners as required
VOM or other test instrument
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Examine the graphics on the following pages and then continue in order to complete a pictorial diagram of each circuit so you can follow your diagram to fabricate the circuit as a working model and test it to prove it meets specifications.

☐ 3. After you fabricate and test the circuit, reference your working model and pictorial diagram as needed to draw a ladder schematic diagram to complete your work.

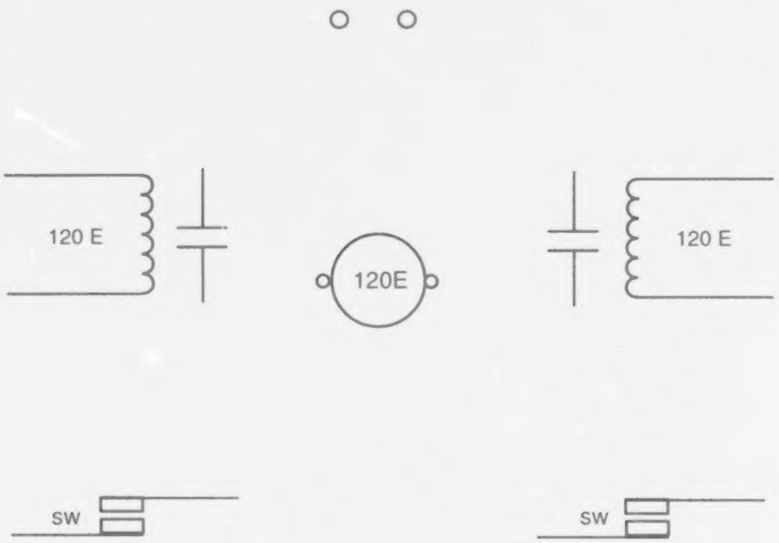
☐ 4. Follow all directions carefully; the pages are designed so that you can reference your pictorial diagram as you complete your ladder diagram.

☐ 5. Number loads and switches as needed, and read all the instructions before you begin so you can ask your instructor for clarification of any part of the job sheet that you do not understand.

Job Sheet 7

☐ 6. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: two SPST switches which control two 120V relay assemblies. Power to the load can be provided from either of the relay assemblies, but only one relay assembly needs to be on to provide voltage to the load while both relay assemblies must be off to stop voltage to the load.

Problem A: Pictorial



☐ 7. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 8. Test your circuit to prove it meets specifications.

☐ 9. Have your instructor check your work.

☐ 10. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 7

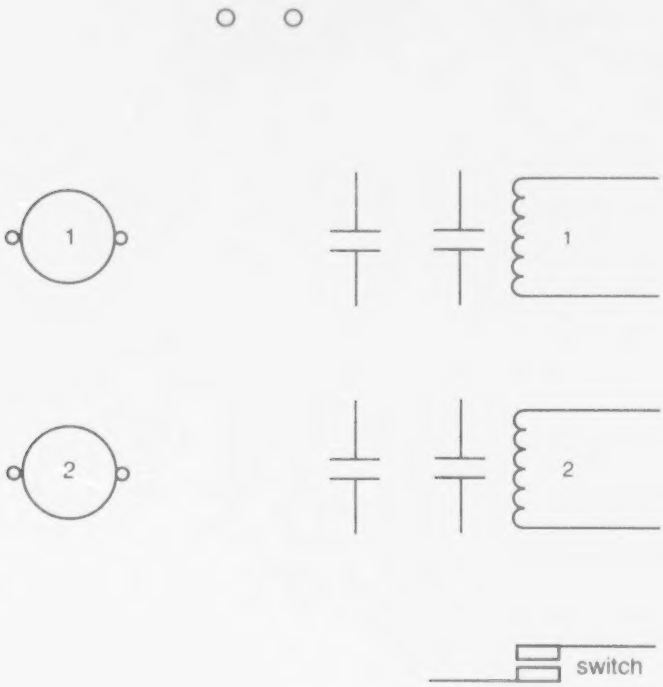
Problem A: Ladder Schematic

☐ 11. Have your instructor check your ladder schematic diagram.

Job Sheet 7

☐ 12. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: have the SPST switch start relay 1 which will energize load 1 and relay 2. When the switch is open, load 1 and relay 1 will be dead, but load 2 will stay energized through relay 2.

Problem B: Pictorial



☐ 13. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 14. Test your circuit to prove it meets specifications.

☐ 15. Have your instructor check your work.

☐ 16. Use your working model and pictorial diagram as guides to complete a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 7

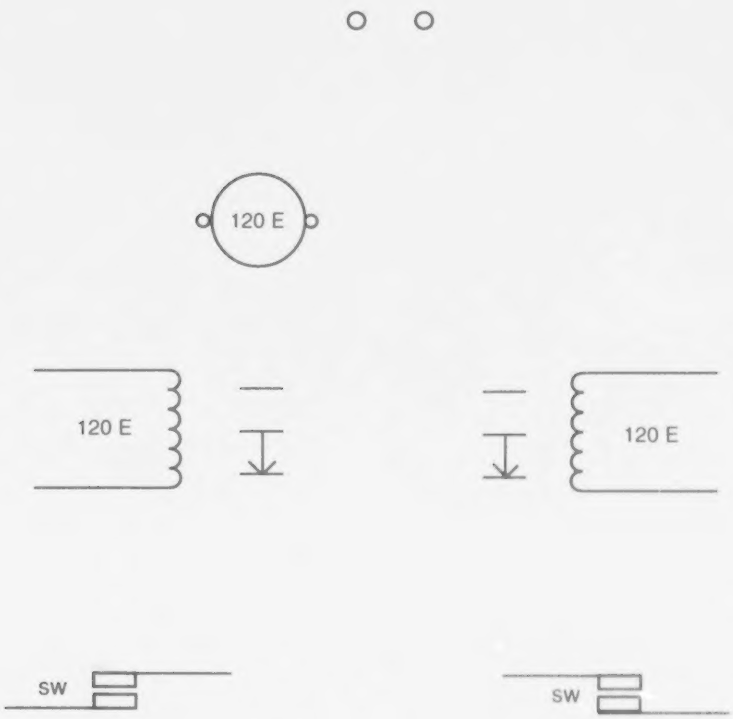
Problem B: Ladder Schematic

☐ 17. Have your instructor check your ladder schematic diagram.

Job Sheet 7

☐ 18. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: the switches and relays indicated stop and start a load, and with both switches open or both switches closed the light will stay on.

Problem C: Pictorial



☐ 19. Use your pictorial as a guide to fabricate a working model of the circuit in your pictorial.

☐ 20. Test your circuit to prove it meets specifications.

☐ 21. Have your instructor check your work.

☐ 22. Use your working model and pictorial diagram as guides to complete a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 7

Problem C: Ladder schematic

☐ 23. Have your instructor check your ladder schematic diagram.

Comments ____

____

____

Transformers and Relays
Unit 6

Job Sheet 8—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Circuits With Special Applications

Name____Attempt Number______

Date____Overall Rating_______

Evaluation Criteria	**Rating**
Number of pictorials completed	_____
Number of ladder schematics completed	_____
Number of working models fabricated to specifications	_____

A. Tools and materials

ACR technician's hand tools
Fabrication/wiring board
Power supply
Conductors of various sizes
Loads as selected by instructor
Fasteners as required
VOM or other test instrument
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Examine the graphics on the following pages and then continue in order to complete a pictorial diagram of each circuit so you can follow your diagram to fabricate the circuit as a working model and test it to prove it meets specifications.

☐ 3. After you fabricate and test the circuit, reference your working model and pictorial diagram as needed to draw a ladder schematic diagram to complete your work.

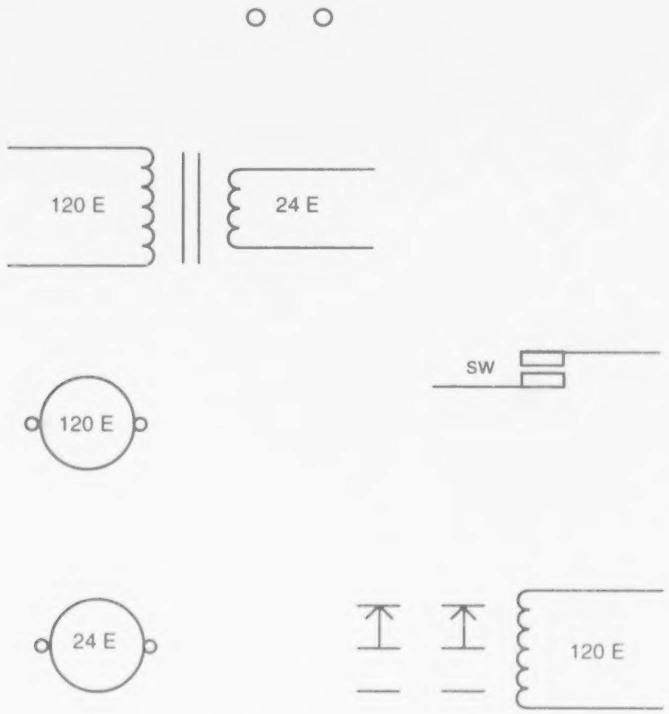
☐ 4. Follow all directions carefully; the pages are designed so that you can reference your pictorial diagram as you complete your ladder diagram.

☐ 5. Number loads and switches as needed, and read all the instructions before you begin so you can ask your instructor for clarification of any part of the job sheet that you do not understand.

Job Sheet 8

☐ 6. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: when the SPST switch is turned on, the top load receives 120V and the bottom load receives 0V. When the switch is turned off, the top load recieves 0V and the bottom load receives 24V.

Problem A: Pictorial



☐ 7. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 8. Test your circuit to prove it meets specifications.

☐ 9. Have your instructor check your work.

☐ 10. Use your working model and pictorial diagram as a guide to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 8

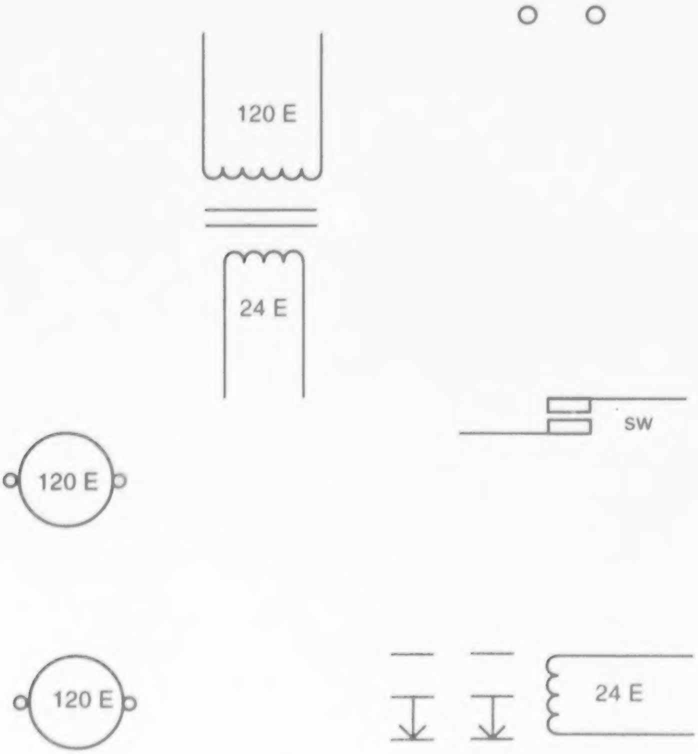
Problem A: Ladder Schematic

☐ 11. Have your instructor check your ladder schematic diagram.

Job Sheet 8

☐ 12. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: with the switch turned on, each load receives 120V through the relay contacts.

Problem B: Pictorial



☐ 13. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 14. Test your circuit to prove it meets specifications.

☐ 15. Have your instructor check your work.

☐ 16. Use your working model and pictorial as a guide to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 8

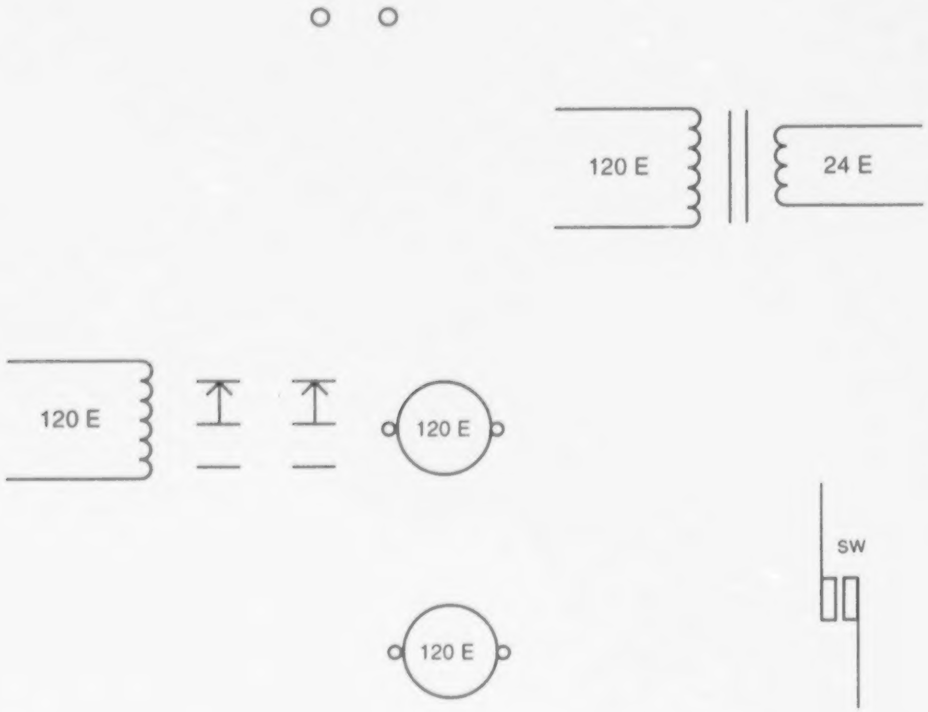
Problem B: Ladder Schematic

☐ 17. Have your instructor check your ladder schematic diagram.

Job Sheet 8

☐ 18. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: with the switch on, each load will receive its specified voltage.

Problem C: Pictorial



☐ 19. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 20. Test your circuit to prove it meets specifications.

☐ 21. Have your instructor check your work.

☐ 22. Use your working model and your pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 8

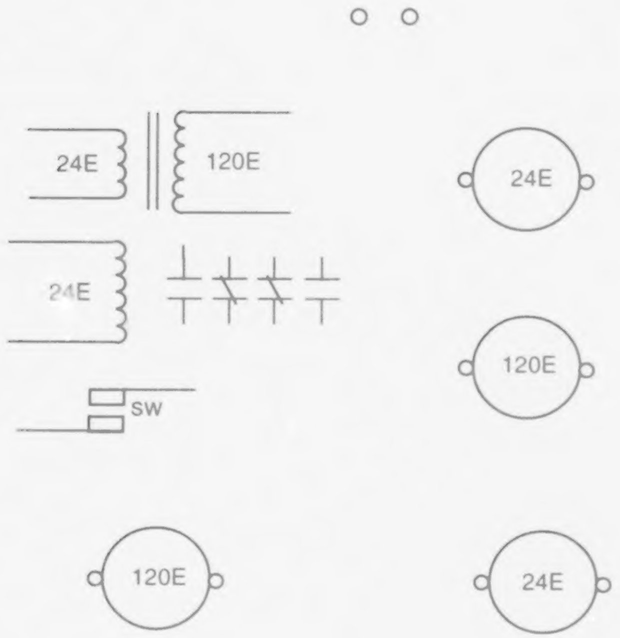
Problem C: Ladder Schematic

☐ 23. Have your instructor check your ladder schematic diagram.

Job Sheet 8

☐ 24. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: with the switch closed, each load receives its specified voltage through the relay.

Problem D: Pictorial



☐ 25. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 26. Test your circuit to prove it meets specifications.

☐ 27. Have your instructor check your work.

☐ 28. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 8

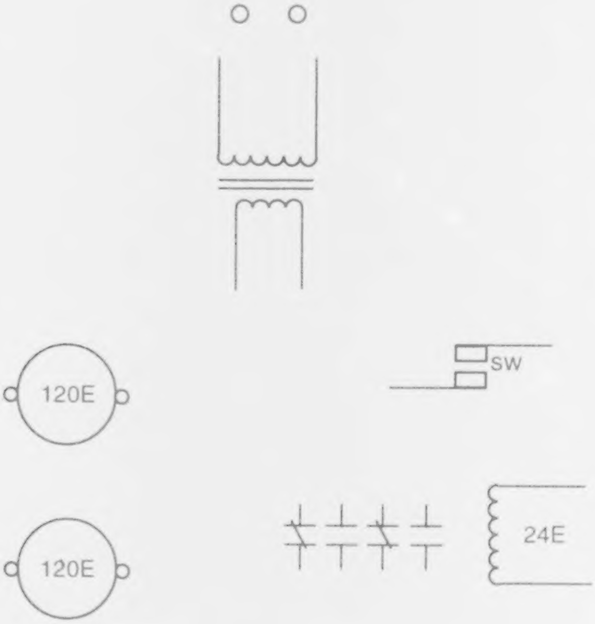
Problem D: Ladder Schematic

☐ 29. Have your instructor check your ladder schematic diagram.

Job Sheet 8

☐ 30. Use the following graphic to draw a pictorial diagram to the following specifications: design a vibrator circuit so that the 120V load is energized through the relay in such a way that it goes on and off rapidly.

Problem E: Pictorial



☐ 31. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 32. Test your circuit to prove it meets specifications.

☐ 33. Have your instructor check your work.

☐ 34. Use your working model and your pictorial diagram as guides to draw a ladder schematic in the space provided on the opposite page.

Job Sheet 8

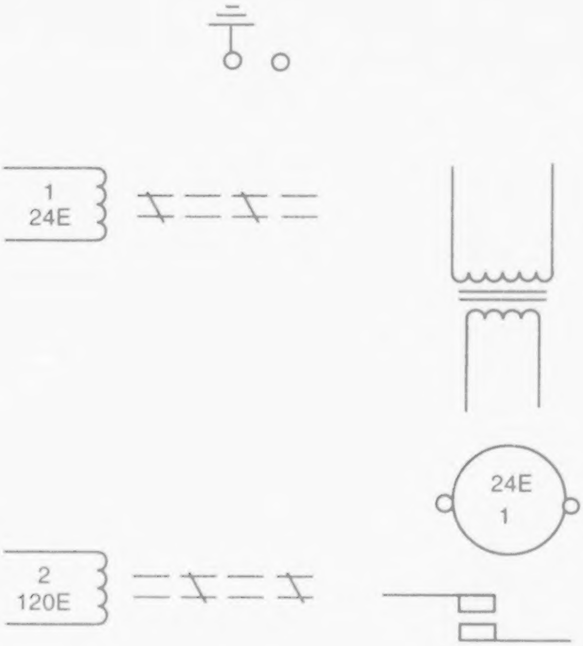
Problem E: Ladder Schematic

☐ 35. Have your instructor check your ladder schematic diagram.

Job Sheet 8

☐ 36. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: an SPST switch is used to make relay 1; relay 1 will make relay 2, and relay 2 will break load 1.

Problem F: Pictorial



☐ 37. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 38. Test your circuit to prove it meets specifications.

☐ 39. Have your instructor check your work.

☐ 40. Use your working model and your pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 8

Problem F: Ladder Schematic

☐ 41. Have your instructor check your ladder schematic diagram.

Comments ____

____

____

Transformers and Relays
Unit 6

Job Sheet 9—Draw Pictorials, Fabricate Working Models, and Draw Ladder Schematics for Circuits With Multiple Relays

Name____Attempt Number______
Date____Overall Rating_______

Evaluation Criteria	Rating
Number of pictorials completed	_____
Number of ladder schematics completed	_____
Number of working models fabricated to specifications	_____

A. Tools and materials

ACR technician's hand tools
Fabrication/wiring board
Power supply
Conductors of various sizes
Loads as selected by instructor
Fasteners as required
VOM or other test instrument
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Examine the graphics on the following pages and then continue in order to complete a pictorial diagram of each circuit so you can follow your diagram to fabricate the circuit as a working model and test it to prove it meets specifications.

☐ 3. After you fabricate and test the circuit, reference your working model and pictorial diagram as needed to draw a ladder schematic diagram to complete your work.

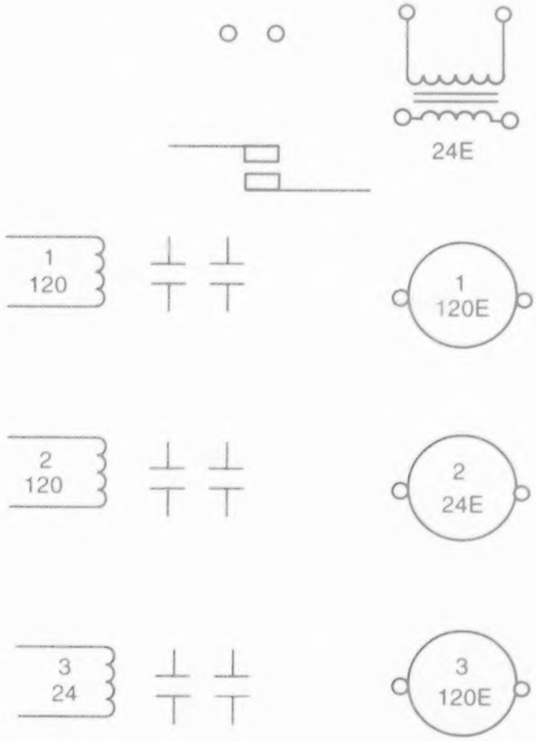
☐ 4. Follow all directions carefully; the pages are designed so that you can reference your pictorial diagram as you complete your ladder diagram.

☐ 5. Read all the instructions before you begin so you can ask your instructor for clarification of any part of the job sheet that you do not understand.

Job Sheet 9

☐ 6. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: an SPST switch energizes relay 1, relay 1 energizes load 1 and relay 2, relay 2 energizes load 2 and relay 3, and relay 3 energizes load 3. When the switch is turned "off" all loads and relays stay on.

Problem A: Pictorial



☐ 7. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 8. Test your circuit to prove it meets specifications.

☐ 9. Have your instructor check your work.

☐ 10. Use your working model and pictorial diagram as guides to draw a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 9

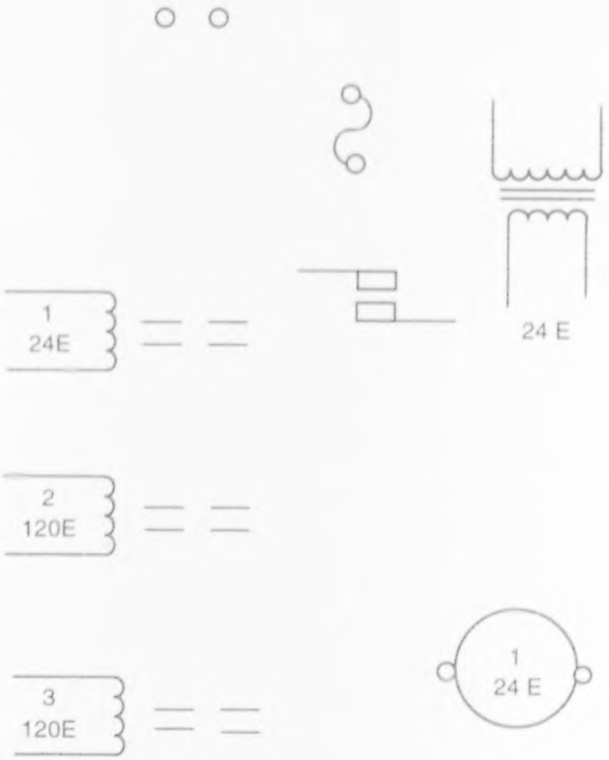
Problem A: Ladder Schematic

☐ 11. Have your instructor check your ladder schematic diagram.

Job Sheet 9

☐ 12. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: an SPST switch energizes relay 1, relay 1 energizes relay 2, relay 2 energizes relay 3, and relay 1 and relay 3 are in series to furnish required voltage to load 1. Protect all circuits with the fuse.

Problem B: Pictorial



☐ 13. Use your pictorial diagram as a guide to fabricate a working model of the circuit in your pictorial.

☐ 14. Test your circuit to prove it meets specifications.

☐ 15. Have your instructor check your work.

☐ 16. Use your working model and pictorial diagram as guides to complete a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 9

Problem B: Ladder Schematic

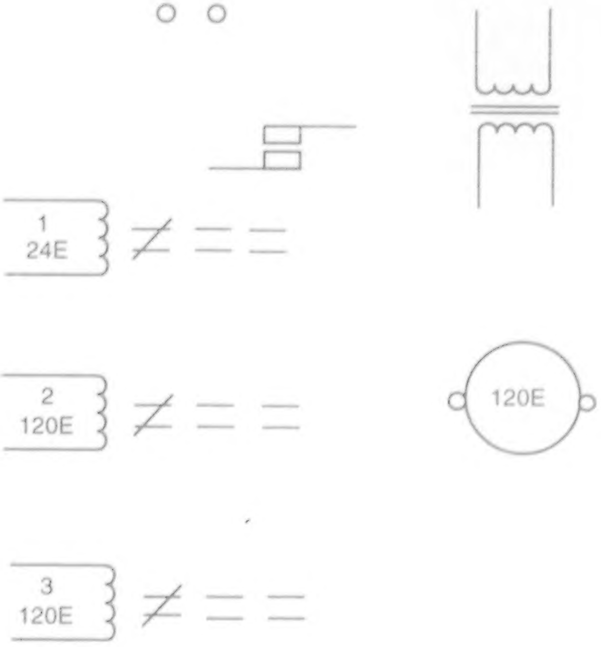
☐ 17. Have your instructor check your ladder schematic diagram.

Job Sheet 9

☐ 18. Use the following graphic as a guide to draw a pictorial diagram to the following specifications: an SPST switch energizes relay 1 which energizes load 1 and relay 2. Relay 2 energizes relay 3, and the contacts in relay 3 must be so arranged that they break relay 1 which in turn breaks load 1.

Note: There should be a flash of light and then nothing.

Problem C: Pictorial



☐ 19. Use your pictorial as a guide to fabricate a working model of the circuit in your pictorial.

☐ 20. Test your circuit to prove it meets specifications.

☐ 21. Have your instructor check your work.

☐ 22. Use your working model and pictorial diagram as guides to complete a ladder schematic diagram in the space provided on the opposite page.

Job Sheet 9

Problem C: Ladder schematic

☐ 23. Have your instructor check your ladder schematic diagram.

Comments ____

____

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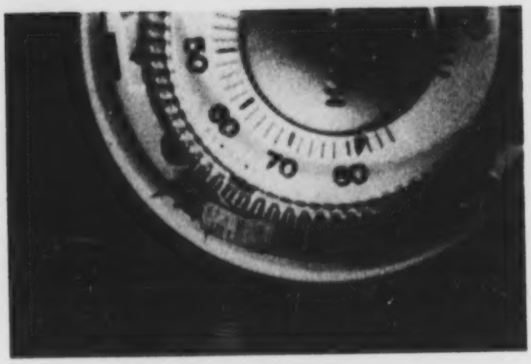


Thermostats

Unit 7

Objective Sheet

Unit Objective

After completing this unit, the student should be able to install a wall thermostat and determine heat anticipation and install an electronic thermostat. The student should demonstrate these competencies by completing activities in the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to thermostats with their correct definitions.
2. Complete statements about thermostat types and their applications.
3. Complete statements about temperature sensors.
4. Solve problems about electrical contacts.
5. Complete statements about major components of a heating/cooling thermostat.
6. Complete statements about heating thermostat anticipation.
7. Complete statements about cooling thermostat anticipation.
8. Identify and solve problems about installing heating/cooling thermostats.
9. Complete statements about multistage thermostats.
10. Complete statements about subbase applications.
11. Match basic internal thermostat switching with controls and external wiring.
12. Identify and solve problems about programmable thermostat applications.

Objective Sheet

13. Select true statements about electronic thermostat characteristics.

14. Select true statements about additional benefits of solid-state thermostats.

15. Complete statements about special applications of line voltage thermostats.

16. Install a wall thermostat and determine heat anticipation. (Job Sheet 1)

17. Replace a thermostat with an electronic programmable thermostat. (Job Sheet 2)

18. Program a programmable thermostat. (Job Sheet 3)

Thermostats
Unit 7

Information Sheet

1. **Terms and definitions**

    a. **Anticipation**—Causing heating or cooling equipment to respond before conditioned space temperatures reach desired settings

    b. **Differential**—The difference between the minimum and maximum temperature to which a thermostat responds when the thermostat is set to a desired setting

    c. **Electronic**—Having to do with electrical circuits or equipment using semiconductors

    d. **Line voltage**—AC voltage of more than 30V, but usually refers to 110V AC or more

    e. **Low voltage**—AC voltage of 30V or less as used in ACR control circuits

    f. **Millivolt**—One thousandth of a volt

    Note: some heating system controls use voltage in the range of 500 to 750 millivolts DC.

    g. **Temperature sensor**—A device which senses or "feels" temperature and conveys that temperature reading to other devices

    h. **Thermostat**—A device which senses temperature conditions and controls circuits which activate equipment to effect changes in those conditions

2. **Thermostat types and their applications**

    a. Thermostats are controls used to cycle heating, cooling, and refrigeration equipment.

    b. Thermostats for equipment such as window air conditioners, refrigerators, floor furnaces, and unit heaters respond to only a single condition and usually have a single manual setting.

    c. Thermostats for central heating and cooling systems may be manually set or may be capable of automatically switching to heating or cooling, or changing their own settings at predetermined times.

    d. Thermostats may be completely mechanical, state-of-the-art electronic, or some combination of the two.

Information Sheet

e. Thermostats may be part of a complete control center which responds to conditions other than temperature, conditions such as humidity or air quality.

f. Thermostat applications vary with their operating voltages:

   (1) low voltage such as in central heating and cooling systems;

   (2) line voltage such as in window air conditioners and domestic and commercial refrigeration;

   (3) millivolt circuits such as in some wall heaters, floor furnaces, and central heating units.

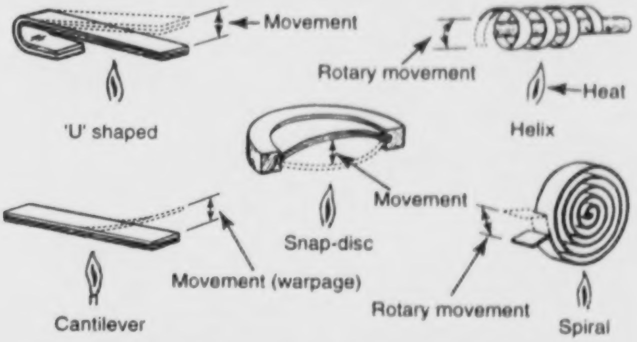
g. ACR technicians must be able to install, operate, and service different types of thermostats and explain thermostat operations to a customer.

3. **Temperature sensors**

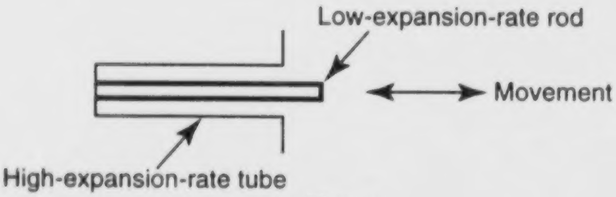
   a. The temperature sensor which reacts to temperature change is the main component in a thermostat.

   b. Types of temperature sensors include:

      (1) Bimetal strip types operate on the principle that two metals fastened together expand at different rates when heated.

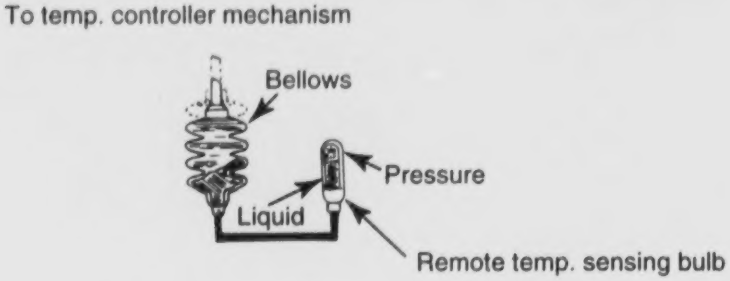

Movement
Rotary movement
Heat
'U' shaped
Helix
Movement
Snap-disc
Movement (warpage)
Cantilever
Rotary movement
Spiral

      (2) Rod and tube types operate on the same expansion principle with a rod of one metal inserted in a tube of a different metal.


Low-expansion-rate rod
Movement
High-expansion-rate tube

Information Sheet

(3) Gas/liquid-filled bulb or tube and bellows types operate on the principle that gas expands when heated and exerts pressure on a bellows.


To temp. controller mechanism
Bellows
Pressure
Liquid
Remote temp. sensing bulb

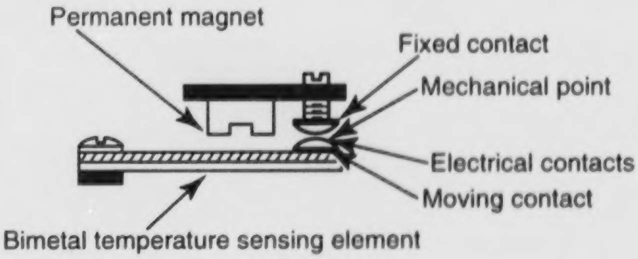
(4) Thermocouple-type sensors use the principle that certain metals when bonded together and heated create very small amounts of voltage.

(5) Electrical resistance types use resistors whose resistance changes as their temperatures change.

4. **Electrical contacts**

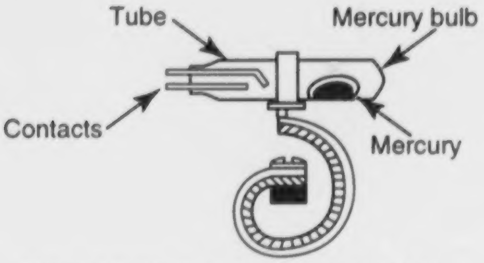
a. Thermostat electrical contacts may be mechanical, mercury bulb, or solid-state.

b. Mechanical contacts are usually connected to some type of bimetal and sometimes use a magnet to make them close with a snap action to prevent arcing.


Permanent magnet
Fixed contact
Mechanical point
Electrical contacts
Moving contact
Bimetal temperature sensing element

c. Some mechanical contacts and all mercury bulb contacts are hermetically sealed inside glass tubes to prevent arcing and protect the contacts from dust and moisture.

d. Mercury tubes or bulbs contain contact probes along with a small globule of liquid mercury.

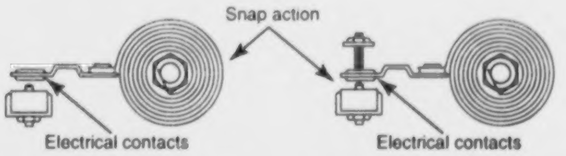

Tube
Mercury bulb
Contacts
Mercury

Bimetel temperature sensing element

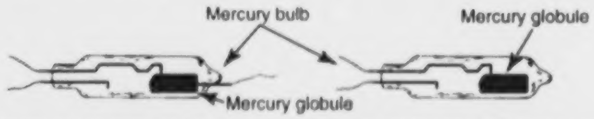
e. The mercury bulb is fastened to a bimetal, usually a spiral bimetal which tilts the bulb with temperature change.

f. As the bulb tilts, the mercury globule completes the circuit between contacts as it falls to one end or the other of the bulb.

g. Thermostat temperature switching action may be single pole, single throw, or single pole, double throw.


Snap action
Electrical contacts
Electrical contacts

Single Pole Single Throw **Single Pole Double Throw**


Mercury bulb
Mercury globule
Mercury globule

Single Pole Single Throw **Single Pole Double Throw**

5. **Major components of a heating/cooling thermostat**

a. Thermostats are designed with three major components which may or may not be separable:

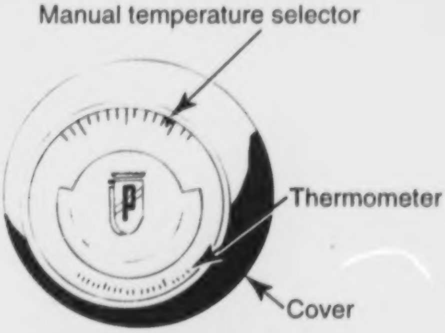
(1) a decorative cover.

(2) a thermostat body.

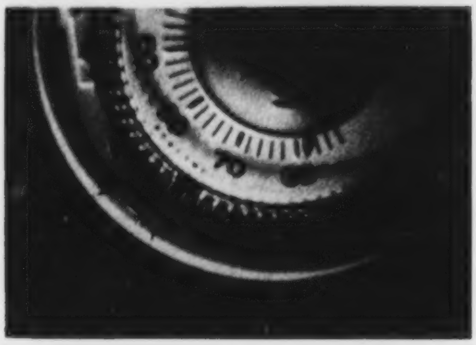
(3) a subbase.

Information Sheet

b. The cover usually contains a thermometer and sometimes a manual temperature selector.


Manual temperature selector
Thermometer
Cover

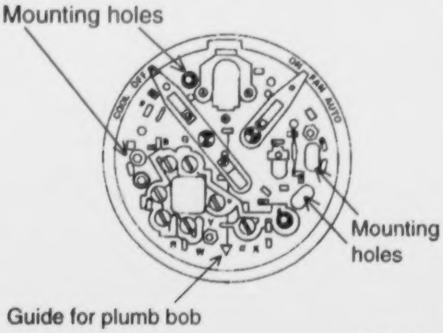
c. The thermostat body contains the temperature sensing element, temperature electrical contacts, usually a heat anticipator, and sometimes a manual temperature selector.

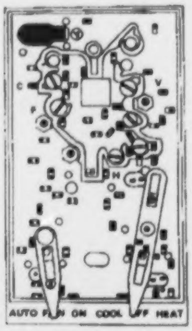


d. The subbase contains any manual switches, terminals for wiring connections, and a cooling anticipator, if one is used.

e. Even though all thermostats contain the same basic components, OEMs sometimes combine the components in different ways.

f. The subbase or the subbase and thermostat body, if they are a single piece, will have mounting holes, and usually guides, to mount and level the thermostat.


Mounting holes
COOL OFF
ON FAN AUTO
Mounting holes
Guide for plumb bob


AUTO FAN ON COOL OFF HEAT

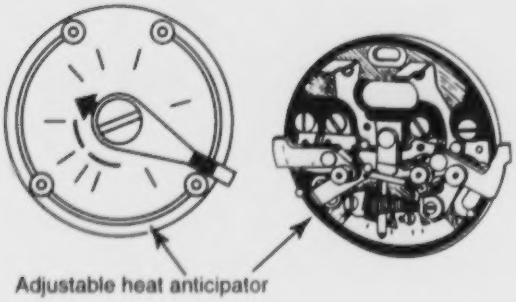
g. All thermostats look better if they are mounted level; in fact, mercury bulb thermostats must be level to operate properly.

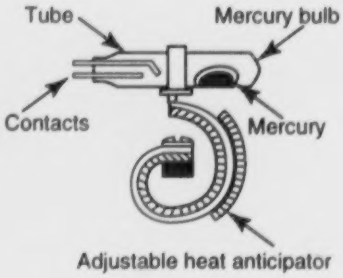
6. **Heating thermostat anticipation**

a. When a heating unit is shut off, some heated air will remain in the unit, and as this air is distributed to the conditioned space, it causes the temperature of the conditioned space to overshoot the desired setting.

b. The thermostat must anticipate the amount of overshoot and turn the heating off before the temperature of the conditioned space reaches the desired setting.

c. A heating anticipator is a resistor connected in series with the thermostat contacts, and the resistor warms the temperature-sensing element while heating is being called for.





d. The added heat of the resistor causes the thermostat to cease calling for heating approximately 1°F before the temperature in the conditioned space reaches the desired setting.

e. Some heating anticipators, such as on millivolt thermostats, are fixed and preset and some are adjustable and must be set to match the current draw of the heating control loads activated by the thermostat.

Note: Never bypass heating control loads with a jumper wire or other device because the heat anticipator will overheat and open.

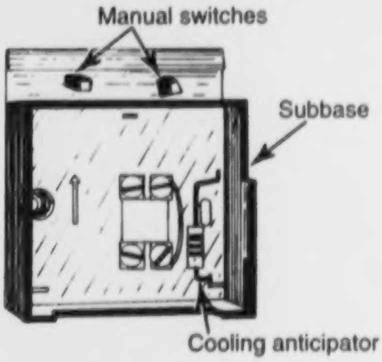
Information Sheet

7. Cooling thermostat anticipation

a. When a cooling unit is turned on, it takes some time for the unit to begin producing cool air, and during that time, the conditioned space could become warmer than the desired setting.

b. The thermostat must anticipate the need for cooling in advance and turn on the cooling unit before the temperature of the conditioned space exceeds the desired setting.

c. A cooling anticipator is a fixed resistor connected parallel to thermostat contacts, and in series with the cooling control loads, and the resistor warms the temperature-sensing element while cooling is not being called for.



d. The added heat of the resistor causes the thermostat to call for cooling approximately 1°F before the temperature in the conditioned space exceeds the desired setting.

8. Installing heating/cooling thermostats

a. Heating/cooling thermostats are usually installed on a wall or other stationary surface or suspended in the conditioned space on a conduit box.

b. A thermostat should be mounted level and four to five feet above the floor.

c. A thermostat should be fastened securely so that it will not move or get out of level if bumped.

d. If a thermostat is mounted on sheetrock or other lightweight material, use anchors designed for the material; do not rely on just screws.

e. A thermostat must be located in the conditioned area so that air will circulate freely around it, and not be blocked by furniture, opened doors, or other obstructions.

Information Sheet

f. The best location for a thermostat is usually in the path of the air returning to the air-handling unit.

g. Thermostats should be located away from hot or cold influences such as:

   (1) appliances.

   (2) lamps.

   (3) direct sunlight.

   (4) drafts.

   (5) walls with warm areas on the other side, areas like kitchens, utility rooms, and baths.

   (6) outside walls.

   (7) electronic devices such as TVs, stereos, or computers.

h. If the thermostat has an adjustable anticipator, be sure to check heating control load amp draw at the thermostat and set the anticipator to match.

i. If you are replacing a thermostat that has a mercury bulb element, do not throw the element in the trash; the mercury is toxic and the element should be placed in a toxic waste container for proper disposal.

9. **Multistage thermostats**

a. Thermostats are often used for more than a single heating and/or cooling function which means that the thermostat must react to more than one temperature condition.

b. Thermostats are usually:

   (1) single-stage heat or single-stage cooling.

   (2) single-stage heat and single-stage cooling.

   (3) single-stage heat and two-stage cooling.

   (4) two-stage heat and single-stage cooling.

   (5) two-stage heat and two-stage cooling.

c. Two-stage heating or cooling is accomplished with two switches, usually mercury bulb, on one bimetal.

Information Sheet

d. The switches in a two-stage thermostat have a 2°F differential between switches.

e. In two-stage cooling thermostats, both switches are open at the set temperature; the first stage closes at approximately 2°F above the set temperature, and the second stage will close if temperature continues to rise to approximately 4°F above the set temperature.

f. In two-stage heating thermostats, both switches are open at the set temperature; the first stage closes at approximately 2°F below the set temperature, and the second stage will close if the temperature continues to drop approximately 4°F below the set temperature.

g. Two-stage cooling thermostats control two cooling capacities such as a single unit with two compressors or a system with two condensing units.

h. Two-stage heating thermostats control two heating capacities such as a gas furnace with a two-stage gas valve, an electric furnace with staged heating elements, or a heat pump with supplementary heat.

10. **Subbase applications**

a. Thermostats and subbases must be selected and installed to match the specific application.

b. A thermostat should be selected primarily for the number of stages of heating and/or cooling that have to be controlled.

c. A thermostat can usually be matched with several different subbases.

d. A subbase should be selected not only for the number of stages, but for desired additional functions such as fan control, auxiliary valve or damper control, or heat pump reversing valve control.

e. Subbase terminals must be connected to the proper stages or controls.

f. Common thermostat subbase terminal markings and what they connect to are:

(1) V or R—power from transformer.

(2) F or G—fan control.

(3) H or W—heating, single-stage or first-stage.

(4) C or Y—cooling, single-stage or first-stage.

(5) B—auxiliary heating control.

(6) O—auxiliary cooling control.

Information Sheet

g. Most thermostat manufacturers use R, G, W, Y, B, and O because they represent the colors red, green, white, yellow, blue, and orange which enables the installer to color code the control wiring more easily.

h. Thermostat wire usually comes in a sheathed cable with from two to ten conductors with color-coded insulation.

i. Multistage thermostats often use subscripts along with the standard letter coding to designate terminals for each stage, such as H_1 or W_1 for first stage heating, and H_2 or W_2 for second stage heating.

j. On systems that use separate control power transformers, the subbase used must have an Rh terminal for the heating system power, and an Rc terminal for the cooling system power.

k. When a subbase for a system that uses separate control power transformers is used on a system with only one transformer, the Rh and Rc terminals must be connected together.

11. **Basic internal thermostat switching**

a. Basic internal thermostat switching is similar for both standard and electronic thermostats.

b. Almost all thermostats use a fan switch which has ON and AUTO positions.

c. In the AUTO position, the fan cycles with the cooling, and a separate control turns on the fan for heating.

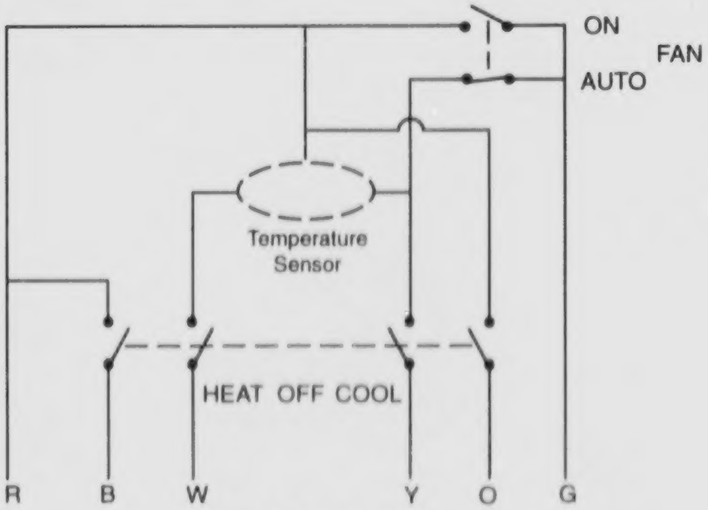
d. In the ON position, the fan runs continuously instead of going on and off with the heating or cooling.

e. The second switch which almost all thermostats use is a system switch which has HEAT OFF COOL positions.

Information Sheet

f. Basic thermostat switches are connected internally to the temperature sensor and to terminals for external wiring as demonstrated in the following schematic.

Note: Remember the guidelines about color coding as presented in Objective 10.



Terminals for external wiring

12. **Programmable thermostat applications**

a. Studies prove that people sleep more comfortably in winter if nighttime temperatures are lowered, and changing temperatures at night or when conditioned areas are unoccupied saves energy because equipment runs less.

b. To help people conserve energy and sleep more comfortably, some thermostats can be programmed to change temperature settings automatically.

Note: Settings can be made manually, but getting up on a cold morning to change the setting on a thermostat can be very uncomfortable.

c. In winter, a home thermostat might be lowered (set back) from 68°F to 60°F starting at 10 p.m. and programmed to return to 68°F at 6 a.m.; this assures the house will be warm by the time people get up.

d. In summer, a home thermostat might be raised (set up) from 72°F to 78°F at 10 p.m. and programmed to return to 72°F at 6 a.m.

e. Temperature ranges for business locations are typically greater, and the times are longer; in winter a business might be programmed to set back from 68°F to 50°F at 5 p.m. and return to 68°F at 7 a.m.; the summer set up is from 72°F to 78°F for the same hours.

Information Sheet

f. Programmable thermostats are either electromechanical or microelectronic; both types perform the same control functions.

g. An electromechanical thermostat uses an electrical timer and is programmed by placing trip pins in a 24-hour dial at the times the program should shift from one temperature to another.

h. An electronic thermostat uses a microprocessor and an electronic clock and is programmed by means of pushbuttons that program a part of the microprocessor memory.

13. Electronic thermostat characteristics

a. An electronic solid-state thermostat uses a small microprocessor to perform many of the functions which are accomplished with electromechanical parts in a standard thermostat.

b. Sensing temperatures, anticipation, cycling rate, and selection of temperature set points are all accomplished electronically which makes them more reliable, more accurate, and more precise.

c. Electronic thermostats use an LED digital display to show such things as current time and temperature, setback or setup time and temperature, and some show humidity levels, display reminders when to change the filter, and show outdoor temperatures.

d. In addition to the standard thermostat components such as subbase and system switches, the electronic thermostat includes a battery to provide power to retain the microprocessor memory anytime voltage is not available to the thermostat.

e. Electronic thermostats mount like a standard thermostat, but it is not necessary to level an electronic thermostat except for appearance.

f. Always disconnect power when mounting a thermostat.

Caution: Failure to disconnect power will result in irreparable damage to some models.

g. Since electronic thermostats use solid-state circuitry and components, most have no field serviceable components.

h. Always check the OEM installation and programming instructions before installing or servicing an electronic thermostat.

Note: Most models will have operating and programming instructions printed on the thermostat cover or concealed behind a pull-out tab or other device.

Information Sheet

14. Additional benefits of solid-state thermostats

a. In addition to performing the functions of electromechanical models, the solid-state thermostat can do many things that were previously not possible.

b. The operation and service of comfort systems has been revolutionized by the capacity of microprocessors to collect and act on large amounts of information.

c. The latest models of programmable thermostats not only change the temperature settings at preset times, but can anticipate when to change the settings based on the unit warm-up and cool-down characteristics and the outdoor temperature.

d. Thanks to the capability of the microprocessor to differentiate between stages and to compare unit capacity with heating demand, setback thermostats for heat pumps are also available.

e. On some models, the technician can use a prescribed procedure to cause a microprocessor based control center to run the system through an abbreviated version of its complete operating cycle.

f. Other models will automatically test the complete system by collecting information from every part of the system and comparing actual system operations with a programmed model of how the system should be operating.

g. Troubleshooting is simplified on many models because the thermostat or control center has alarms and/or digital readouts that display the location of the fault for a technician.

h. The microprocessor has made it possible for controls on systems of any size to evaluate a wide range of variables affecting both comfort control and energy management.

15. Special applications of line voltage thermostats

a. On room air conditioners, domestic refrigerators and freezers, and many commercial refrigeration units, thermostats operate line voltage and use a gas or liquid-filled tube or bulb to sense and respond to temperatures.

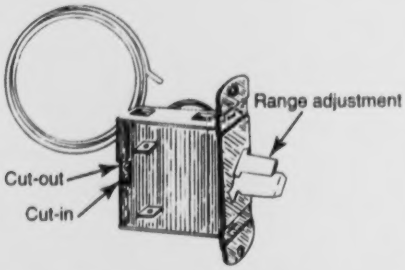
b. The temperature sensing element may sense air temperature or evaporator temperature.

c. Air temperature sensing elements are placed either in the air stream returning to the evaporator or in the middle of the conditioned space, but not in the supply air stream.

Information Sheet

d. Evaporator temperature elements are placed directly in contact with the evaporator, either on the surface or inserted into some type of tube in contact with the evaporator.

e. These thermostats have a range adjustment which is usually a control knob so that a user can adjust the minimum and maximum operating temperature settings.



f. Changing the range adjustment does not change the differential, that is the difference between the minimum, cut-out temperature, and the maximum, cut-in temperature.

g. These thermostats will have either a fixed or an adjustable differential which should be adjusted only by a qualified technician.

h. The differential adjustment is made with one or two screws on the side or back of the thermostat.

Note: Reference the graphic in item e.

i. There are three types of differential adjustments:

(1) a cut-in type in which the cut-in setting can be moved without changing the cut-out setting.

(2) a cut-out type in which the cut-out setting can be moved without changing the cut-in setting.

(3) a cut-in and cut-out type in which both the cut-in and cut-out settings may be moved closer together or moved farther apart.

Thermostats
Unit 7

Job Sheet 1—Install a Wall Thermostat and Determine Heat Anticipation

Name ______________________ Date __________ Attempt Number _____

Evaluation Criteria	**Rating**
Subbase properly wired, secured, and level	_____
Heat anticipation determined and anticipator properly set	_____
Thermostat verified operational	_____

A. Tools and materials

Heating/cooling thermostat and subbase as selected by instructor
An operational heating/cooling system as selected by instructor
ACR technician's hand tools
Mounting screws and/or anchors as required
Scratch awl and screw starter
Four-conductor thermostat cable
Small level or plumb bob
Digital ammeter or Clamp-on ammeter w/ten-loop coil of control wire
Safety glasses

B. Procedure

☐ 1. Read OEM installation instructions if they are available.

☐ 2. Put on safety glasses.

☐ 3. Verify that no voltage is present at the wires in the thermostat cable.

☐ 4. Locate area where thermostat will be installed.

☐ 5. Measure up from the floor about 54 to 60 inches.

☐ 6. Mark a spot to center the subbase.

☐ 7. If the thermostat is attached to the subbase, loosen the retaining screws and remove the thermostat from the subbase.

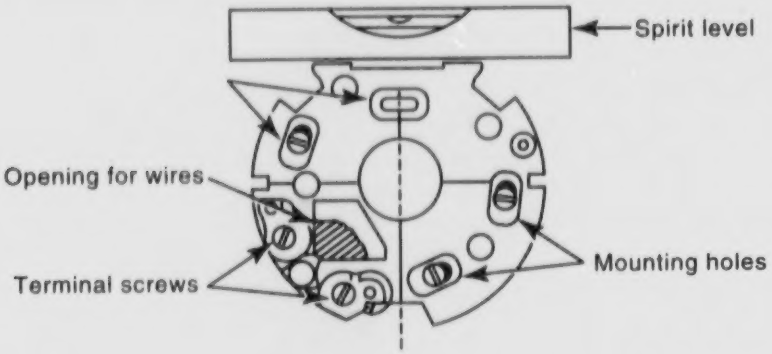
☐ 8. Feed the thermometer wire through the proper opening in the subbase.

Note: You may have to make a new hole in the wall and reroute the wire if it is in the wrong location.

> **Caution:** With some models, you must be careful not to use a screwdriver with too wide a blade; it could enlarge the plastic hole around the screw and allow the screw to fall out.

Job Sheet 1

☐ 9. Hold the subbase up to the wall and use a small level or a plumb bob to check for approximate level.



☐ 10. Select subbase mounting holes that will have a wall surface with a stud or other solid backing behind them.

☐ 11. Mark on the wall through the subbase mounting holes, spots for the mounting screws or anchors.

Note: If you are mounting the thermostat on a sheetrock wall or a wall made of lightweight construction material, use anchors; screws alone will not secure the thermostat well enough to keep it firmly in place.

☐ 12. Mark in the center of elongated slots so these can be used to level the subbase.

☐ 13. Lay the subbase aside and use a scratch awl to start holes for the screws, or install anchors if there is not solid backing behind the marks you have made for the screws.

☐ 14. Feed the thermostat wire through the proper opening in the subbase.

☐ 15. Place the subbase on the wall and screw or anchor it into place, but leave the screws or anchors loose enough that the subbase can still be moved with slight pressure.

☐ 16. Check the subbase with the level, and adjust as necessary.

☐ 17. Tighten the screws or anchors and check the level again.

☐ 18. Make sure no wires cross places that would interfere with subbase or thermostat installation.

☐ 19. Strip 1/2" of insulation from each conductor.

Job Sheet 1

☐ 20. Connect the red wire to the R or V terminal.

☐ 21. Connect the white wire to the W or H terminal.

☐ 22. Connect the green wire to the G or F terminal.

☐ 23. Connect the yellow wire to the Y or C terminal.

Note: Some thermostat cables may have a blue (B) wire instead of a yellow (Y) wire.

☐ 24. Push the wires back so that they will not interfere with the thermostat installation or operation.

☐ 25. Seal the opening through which the wires entered.

☐ 26. Have your instructor check your work.

☐ 27. Check the level of the thermostat again, and tighten the screws or anchors securely, but be careful not to overtighten and crack the thermostat subbase.

☐ 28. Connect ends of a ten-loop coil to R and W terminals on the subbase, or a single loop of wire if you are using a digital ammeter.

☐ 29. Have your instructor check your work.

☐ 30. Turn on power to heating unit, and verify that unit is operating: yes ☐; no ☐.

☐ 31. Clamp the ammeter through the ten-loop coil or clamp the digital ammeter through the single loop.

☐ 32. Read ammeter reading and divide the reading by the number of loops in the coil: reading ______________ divided by 10 ____________ .

Example: Ammeter reads 4A; 4 divided by 10 = .4A. Digital ammeter reads .4A; does not require division.

☐ 33. Have your instructor check your work.

☐ 34. Turn off power to heating unit.

☐ 35. Locate the anticipator adjustment on the thermostat which should show a scale.

☐ 36. Set the heat anticipator on the thermostat to match your amperage determination.

Job Sheet 1

☐ 37. Align thermostat on subbase, and tighten all the screws that hold the thermostat to the subbase.

Note: The screws will be held in place on the thermostat by retainers, so be sure the thermostat is properly aligned with the subbase so the screws will line up with the holes in the subbase.

☐ 38. Have your instructor check your work.

☐ 39. Place the cover on the thermostat.

☐ 40. Set HEAT OFF COOL switch to OFF and set thermostat to the lowest temperature setting, and turn the fan switch to AUTO.

☐ 41. Turn the power to the heating unit ON.

☐ 42. Turn fan switch to ON and verify that fan operates, and then return fan to auto: yes ☐ ; no ☐.

☐ 43. If fan does not operate, check all connections again; if it still does not operate, talk with your instructor.

☐ 44. Turn system switch to HEAT and thermostat to highest temperature setting.

☐ 45. Verify that heat comes on: yes ☐ ; no ☐.

☐ 46 If heat does not come on, check all connections again; if heat still does not come on, talk with your instructor.

☐ 47. Turn system switch to COOL and thermostat to lowest temperature setting.

☐ 48. Verify that cooling comes on: yes ☐ ; no ☐.

☐ 49. If cooling does not come on, check all connections again; if cooling still does not come on, talk with your instructor.

☐ 50. Return settings to OFF and AUTO.

☐ 51. Have your instructor check your work.

☐ 52. Clean up area and return tools and materials to proper storage.

Comments: ____

____

____

Thermostats
Unit 7

Job Sheet 2—Replace a Thermostat With an Electronic Programmable Thermostat

Name______________________________ Date________Attempt Number____

Evaluation Criteria	**Rating**
Wire colors and terminals identified at removal	_____
New thermostat properly installed and leveled	_____
Fan, heat, and cooling functions verified operational	_____

A. Tools and materials

Electronic programmable thermostat
Operational heating/cooling system w/standard thermostat as selected by instructor
ACR technician's hand tools
Drill w/assorted drill bits
Small level
OEM installation and operation instructions
Analog ammeter and 10-wrap coil or digital ammeter
Safety glasses

B. Procedure

☐ 1. Read the OEM instructions.

☐ 2. Put on safety glasses.

☐ 3. Shut off power to the system.

☐ 4. Remove front cover from the old thermostat.

☐ 5. Remove thermostat from the subbase, if it is a two-piece model.

☐ 6. Remove entire thermostat from the wall without disconnecting the wires, if it is a single-piece model.

☐ 7. Identify each wire attached to the old thermostat by color and terminal designation, and record the information here:

____

____

____

Job Sheet 2

☐ 8. If necessary, label the wires so that difficult to identify wires or duplicate colors on wires will not be confusing.

Note: Labels and directions for their use may be enclosed with the new thermostat.

☐ 9. Disconnect the wires from the old thermostat, being careful not to let the wires fall back into the wall.

☐ 10. Remove the thermostat components from the packing material, remove cover and/or separate components if necessary.

☐ 11. Examine the back of the thermostat and OEM instructions to identify switches which must be set to match the application.

☐ 12. Check OEM instructions and set switches as necessary to match the type of system on which you are working.

Note: It may be necessary to check the amp draw of the system during heating in order to determine switch settings; see Job Sheet 1 for this procedure.

☐ 13. Hold the subbase or thermostat up to the wall, feed thermostat wires through the back of the subbase or thermostat, and use a small level to check for approximate level.

☐ 14. Align mounting holes with the original holes in the wall, or mark mounting hole locations on the wall.

☐ 15. Move base out of the way and drill screw or anchor holes as required.

☐ 16. Install anchors, if used.

☐ 17. Feed the thermostat wires through the proper opening in the subbase or thermostat, place the subbase on the wall, and loosely install the mounting screws.

☐ 18. Level the thermostat and tighten the screws.

Note: Leveling is for appearance only and will not affect thermostat operation.

☐ 19. Connect control wires to thermostat subbase terminals according to wiring diagrams or tables provided in the installation instructions.

Note: If the thermostat is a single piece model, wires must be connected to the thermostat before mounting it to the wall.

Job Sheet 2

☐ 20. Push any excess control wire into the wall and seal the hole around the wire to prevent drafts from affecting thermostat operation.

☐ 21. Add jumper wires between terminals as indicated in the installation instructions.

Note: Jumper wires are required to adapt some models for single transformer use, heat pump applications, and other special applications.

☐ 22. Install required batteries.

☐ 23. Attach thermostat to subbase and replace covers as indicated in the instructions.

☐ 24. Consult instructions and familarize yourself with the thermostat features, the display, and the location and operation of the thermostat buttons and switches.

☐ 25. Make sure the thermostat fan switch is in the AUTO position and the system switch is in the OFF position.

☐ 26. Turn on power to the system.

☐ 27. Move fan switch to ON position and check to see if the blower comes on as it should: yes ☐ ; no ☐ .

☐ 28. Move fan switch to AUTO position and check to see if the blower goes off as it should: yes ☐ ; no ☐ .

☐ 29. Move system switch to HEAT position, adjust temperature setting above room temperature, and check to see if the heat comes on: yes ☐ ; no ☐ .

Note: It may be necessary to light the pilot.

☐ 30. Adjust temperature setting below room temperature and check to see if the heat goes off: yes ☐ ; no ☐ .

☐ 31. Move system switch to COOL position, adjust thermostat setting below room temperature, and check to see if the blower comes on and cooling begins: yes ☐ ; no ☐ .

☐ 32. Adjust temperature setting below room temperature and check to see if cooling stops: yes ☐ ; no ☐ .

☐ 33. Have your instructor check your installation and operational checks.

Job Sheet 2

☐ 34. Clean up area and return tools and materials to proper storage.

Comments: ____

____

____

Thermostats
Unit 7

Job Sheet 3—Program a Programmable Thermostat

Name ______________________ Date ____________ Attempt Number ____

Evaluation Criteria	**Rating**
Program time periods planned and recorded	_____
Times properly programmed into thermostat	_____
Program entries verified by day and time	_____

A. Tools and materials

Heating/cooling system w/programmable thermostat installed
OEM operating instructions

B. Procedure

☐ 1. Read OEM programming instructions.

☐ 2. Consult with your instructor to determine the time periods and heating and cooling temperatures to be programmed into the thermostat.

☐ 3. Use the Thermostat Programming Table accompanying this job sheet to plan your program time periods and the temperatures for each period.

☐ 4. Plan your offset periods to end approximately 30 minutes before the time the activity temperature is desired.

Example:

Day	Activity Times		Heating offset times		Heating temp.	Cooling offset times		Cooling temp.
MON								
	Wake	6:00AM	End	5:30AM	70°	End	5:30AM	70°
	Leave	8:00AM	Begin	8:00AM	63°	Begin	8:00AM	78°
	Return	5:00AM	End	4:30PM	70°	End	4:30PM	70°
	Sleep	10:00AM	Begin	10:00PM	63°	Begin	10:00PM	78°

☐ 5. Some thermostat models will have this 30-minute period preprogrammed; if you have that type, set offset period ending times for the actual time the activity temperature is desired.

Job Sheet 3

☐ 6. If operating instructions differ from the guidelines in this activity, follow the OEM instructions.

☐ 7. Record your plan on the Thermostat Programming Table that accompanies this job sheet.

☐ 8. Have your instructor check your program.

☐ 9. Follow OEM instructions to set the thermostat for the current time and day.

☐ 10. Follow OEM instructions to enter your program into the thermostat.

☐ 11. Follow OEM instructions to view the programming you have entered into the thermostat, and verify that the times and temperatures match the information recorded on your table.

☐ 12. Have your instructor check your programming.

☐ 13. Clean up area and return OEM instruction materials to proper storage.

Comments: ____

____

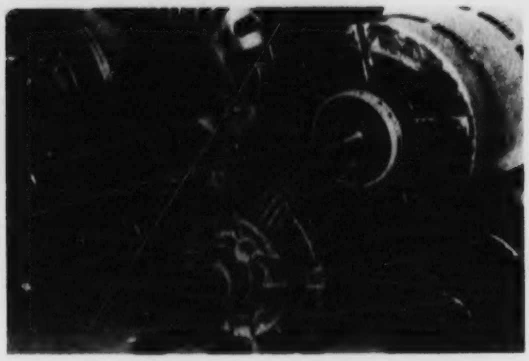
____

Job Sheet 3

Thermostat Programming Guide

Day		Heating Start Time	Heating Temperature	Cooling Start Time	Cooling Temperature
Monday	1. Wake	1.	1.	1.	1.
	2. Leave	2.	2.	2.	2.
	3. Return	3.	3.	3.	3.
	4. Sleep	4.	4.	4.	4.
Tuesday	1. Wake	1.	1.	1.	1.
	2. Leave	2.	2.	2.	2.
	3. Return	3.	3.	3.	3.
	4. Sleep	4.	4.	4.	4.
Wednesday	1. Wake	1.	1.	1.	1.
	2. Leave	2.	2.	2.	2.
	3. Return	3.	3.	3.	3.
	4. Sleep	4.	4.	4.	4.
Thursday	1. Wake	1.	1.	1.	1.
	2. Leave	2.	2.	2.	2.
	3. Return	3.	3.	3.	3.
	4. Sleep	4.	4.	4.	4.
Friday	1. Wake	1.	1.	1.	1.
	2. Leave	2.	2.	2.	2.
	3. Return	3.	3.	3.	3.
	4. Sleep	4.	4.	4.	4.
Saturday	1. Wake	1.	1.	1.	1.
	2. Leave	2.	2.	2.	2.
	3. Return	3.	3.	3.	3.
	4. Sleep	4.	4.	4.	4.
Sunday	1. Wake	1.	1.	1.	1.
	2. Leave	2.	2.	2.	2.
	3. Return	3.	3.	3.	3.
	4. Sleep	4.	4.	4.	4.

Note: Use Saturday entries when Saturday and Sunday are programmed together as "Weekend."



Introduction to Electric Motors

Unit 8

Objective Sheet

Unit Objective

After completing this unit, the student should be able to use a pulley selection chart, solve electric motor problems, and replace a missing V-belt, adjust tension, and check motor operations. The student should demonstate these competencies by completing the activities in the assignment and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to electric motors with their correct definitions.
2. Select true statements about electric motor applications.
3. Complete statements about types of electric motors.
4. Identify and solve problems about basic DC motor operation.
5. Select true statements about basic AC motor operation.
6. Complete statements about single-phase AC motor starting.
7. Select true statements about electronically commutated motors.
8. Match basic AC electric motor parts with their functions.
9. Select true statements about types of motor construction.
10. Identify types of motor mounts and typical applications.
11. Complete statements about motor data plates.

Objective Sheet

12. Select true statements about pulleys and belts.

13. Complete statements about pulley selection.

14. Complete statements about sizing and selecting V-belts.

15. Solve problems about troubleshooting electric motors.

16. Use a pulley selection chart. (Assignment Sheet 1)

17. Solve electric motor problems. (Assignment Sheet 2)

18. Replace a missing V-belt, adjust tension, and check motor operation. (Job Sheet 1)

Introduction to Electric Motors
Unit 8

Information Sheet

1. **Terms and definitions**

   a. **Armature**—That part of a motor or generator that has coils of wire wrapped around a metal core so that current can be induced to produce torque in the motor

   b. **Belt dressing**—A substance applied to pulley belts to reduce noise and increase friction

   c. **Deflection**—The degree of movement that indicates belt tension between two pulleys when the belt is depressed at or near a center point between the pulleys

   d. **Electromagnet**—Insulated wire wound around a soft iron core which becomes a magnet when current flows through the wire

   e. **NEMA**—The National Electrical Manufacturer's Association, a group that establishes standards for electric motors

   f. **Poles**—The laminated, soft iron elements of a stator which have insulated wire wrapped around them to form the main windings in a motor

   g. **Rotor**—A rotating permanent magnet in an AC motor

   h. **Stator**—A stationary electromagnet in an AC motor

   i. **Torque**—Amount of turning capacity

2. **Electric motor applications**

   a. Motors used for different applications require motors with different characteristics; small propeller fan motors are required to do quite different things than large refrigerant compressor motors.

   b. The motor starting a compressor must have high torque to be able to start against a heavy load while a fan motor requires little torque to get started.

   c. Since a motor with high torque is more expensive than a motor with low torque, the motor selected for a given job will be the one with the least torque that can do the job.

   d. Larger motors, particularly in commercial or industrial applications use three-phase, 3Ø, power to achieve required torque.

Information Sheet

e. Almost all smaller motors use different applications of single-phase, 1Ø, power to achieve required torque.

f. An ACR technician must not only be able to identify the different types of motors, but must be able to select the most appropriate motor for a specific application.

3. **Types of electric motors**

a. Types of single-phase AC motors used in ACR equipment include:

(1) shaded-pole.

(2) split-phase.

(3) capacitor start, induction run, CSIR, often referred to as simply capacitor start or CS.

(4) permanent split capacitor, PSC.

(5) capacitor start, capacitor run, CSR.

b. There is only one basic type of three-phase AC motor.

c. Electronically commutated motors, ECMs, are DC motors used to provide variable speed operations.

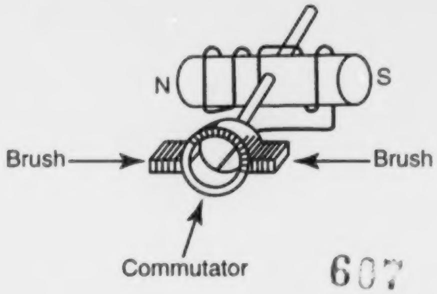
4. **Basic DC motor operation**

a. Most motors used in ACR equipment are AC induction motors, but basic motor operation can best be described by examining DC motor principles.

b. A DC motor, similar to a generator, has both an electric coil and a magnetic field.

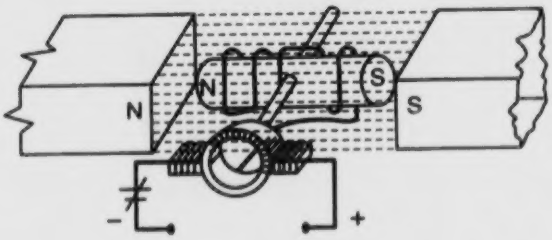
c. The magnetic field is stationary, and the coil rotates within the magnetic field.

d. The coil, called an armature, is mounted on a shaft and connected to DC voltage through a split-ring commutator and brushes that make contact with it.



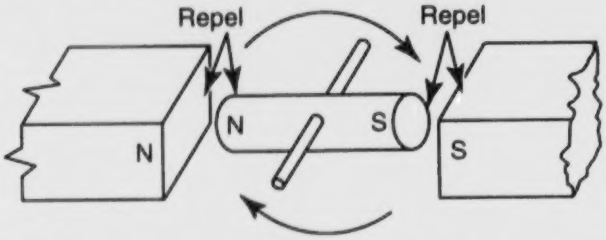
Information Sheet

e. The armature is placed within the magnetic field created by permanent magnets.

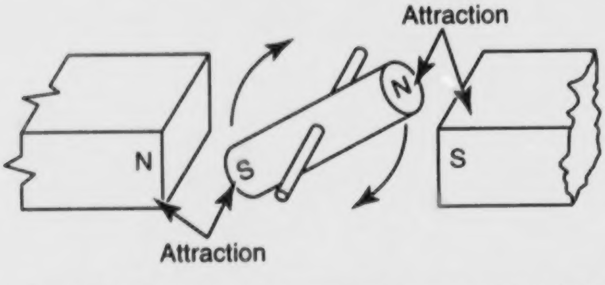


f. The arrangement of the commutator and brushes causes the electricity that flows through the armature to reverse its direction each time the armature rotates half a revolution.

g. Completing the electrical circuit turns the armature into an electromagnet, and since the magnetic poles repel each other, the armature's N and S poles spin away from the N and S poles of the field magnet.



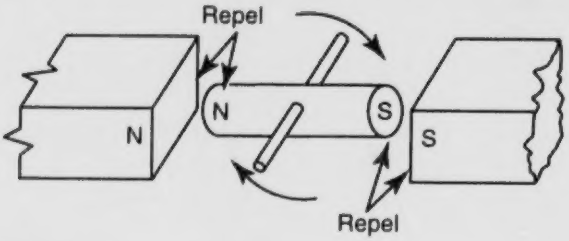
h. Since opposite magnetic poles attract, the N and S poles of the field magnet attract the opposite poles of the armature as the armature turns.



i. Just as the N and S armature poles align themselves with the opposite S and N poles in the field magnet, the commutator/brush arrangement reverses the flow of electricity in the armature.

Information Sheet

j. Since the poles on the armature are reversed electrically, the armature and field magnets repel each other once again and the armature continues to spin.



5. **Basic AC motor operation**

a. An AC induction motor, like a DC motor, has both a coil and a permanent magnetic field.

b. In a DC motor the permanent magnet is stationary and the coil rotates, but in an AC motor the coil is stationary and the permanent magnet rotates.

c. In an AC induction motor, the coil and an iron core form a stationary electromagnet called a stator.

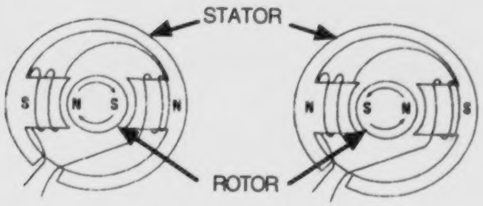
Note: Note the resemblance of the word "stator" to the beginning of the word "stationary."

d. The permanent magnet and the shaft it is mounted on form a rotor which rotates within the stator.

Note: Note the resemblance of the word "rotor" to the beginning of the word "rotate."

e. Since alternating current reverses direction of flow 120 times a second on 60Hz current, the electromagnetic poles of the stator reverse polarity 120 times a second.

f. The stator poles alternately attract and repel the permanent magnetic poles of the rotor as the N and S poles of the stator reverse polarity.



Information Sheet

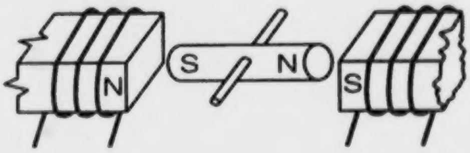
g. The magnetic fields created by winding wires of different sizes and resistance onto the poles within the stator produce torque which causes the motor to start and continue spinning.

h. The windings in an induction motor are either high resistance start windings or low resistance run windings.

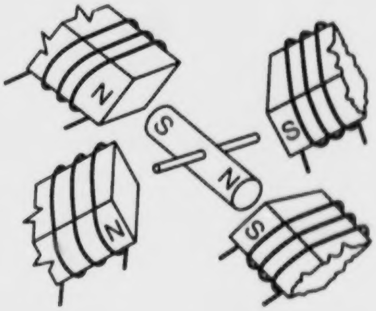
6. Single-phase AC motor starting

a. Once a single-phase motor starts, it will run as long as power is applied to the motor, but once it stops, something must be done to get it started.

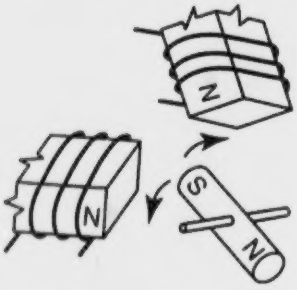
b. In a motor with only one stator pole, the rotor will stop with the N and S poles attracting each other, and without any assistance, the motor will not start again.



c. Adding another stator pole to the motor would appear to solve the problem by providing magnetic attraction to deflect the rotor and start rotation.

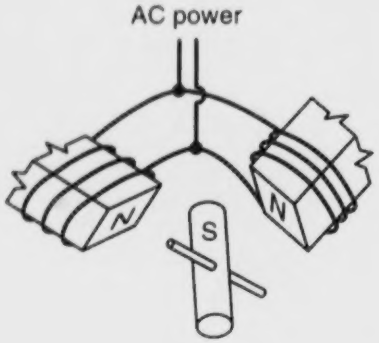


d. If the rotor stops equidistant between two stator poles, equal magnetic attraction by the two poles will once again make the motor unable to start.



Information Sheet

e. The problem of making the motor start can be solved by using a method to make the current around one pole lead or flow ahead of the current around the other pole.



f. When AC power is applied, the pole with the leading current will have a stronger attraction than the pole with the lagging current and rotation will start.

g. Different types of motors use various methods of splitting the phase or creating two-phase current.

Note: Motor starting methods will be discussed in each motor unit that follows.

h. The amount of turning ability created by the phase split is called torque and is the basic difference between all single-phase motors used in ACR applications.

7. **Electronically commutated motors**

a. Electronically commutated motors, ECMs, are brushless DC motors which enable variable speed motor operations such as fans and blowers, and variable volume controls such as refrigerant metering devices.

b. Power for ECMs begins with 1Ø AC voltage which is filtered in the electromagnetic interference, EMI, module which also prevents feedback which could interfere with household electronic devices such as stereos and TVs.

c. The filtered AC current is converted to rectified DC by a diode module, DIOM.

d. Rectified DC is smoothed out by a capacitor placed across the line.

Information Sheet

e. An ECM drive unit converts the DC voltage to a three-phase square-wave voltage and applies it sequentially to the three-phase stator windings in the motor.

f. In an ECM, like in an AC motor, the armature is permanently magnetized which produces a magnetic interaction opposite to that in a standard DC motor.

g. The ECM drive unit reverses the magnetic field electronically instead of using a brush and commutator arrangement which eliminates brushes and commutators and their disadvantages.

h. An ECM operates similar to a three-phase motor; the frequency of the ECM drive signal determines motor speed while current level determines the motor torque.

i. A microprocessor signal tells the ECM drive unit at what speed to run the motor by the frequency of the pulses it sends.

Example: A room thermostat sends a signal to the microprocessor on the control board which tells the ECM drive unit to increase the ECM compressor motor speed in proportion to the cooling desired.

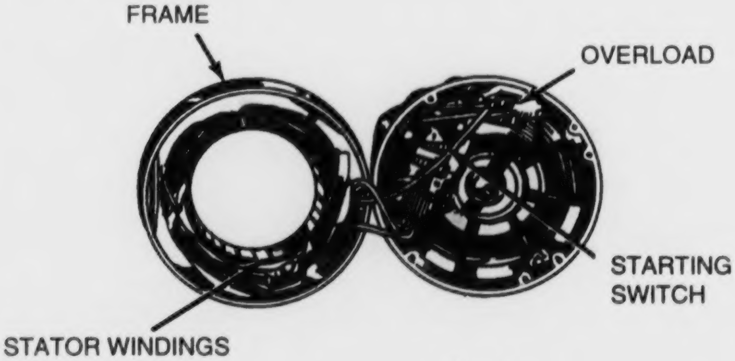
8. **Basic AC electric motor parts and their functions**

a. **Frame**—The housing or body of the motor which contains the stator

b. **Stator**—The iron core and coil of wire wound around it that form the stationary electromagnet

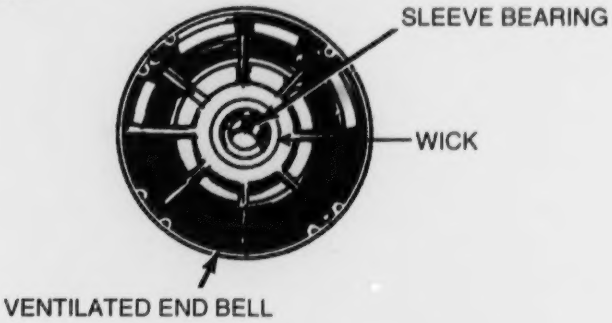
c. **Winding**—The coil of wire in the stator

d. **Overload**—An electrical protection device built into the motor to protect against high temperatures and high current



Information Sheet

e. **End bells**—Parts that contain the bearings and fasten to each end of the frame



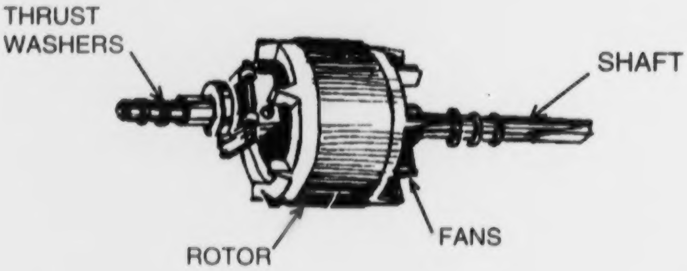
f. **Bearings**—Round parts in the center of an end bell which fit around the shaft and allow the shaft to turn with minimal friction

g. **Sleeve bearing**—A bearing which uses a solid metal sleeve designed to allow oil to flow from the wick to lubricate the shaft

h. **Ball bearing**—A bearing which uses multiple metal balls and grease and is usually permanently prelubricated

i. **Wick**—An absorbant material designed to hold lubricating oil around a sleeve bearing

j. **Rotor**—A permanent magnet which is mounted on a shaft, fits into the stator, and rotates



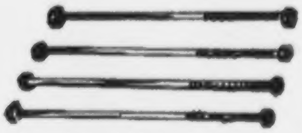
k. **Fans**—Vane-like pieces fastened to the end of the rotor to circulate air which helps cool the motor

l. **Shaft**—A metal rod which fits through the center of the rotor, rotates, and transfers the rotation to such things as blowers and pumps

m. **Thrust washers**—Spacers on the shaft which are used to center the rotor within the stator

Information Sheet

n. **Assembly bolts**—Bolts that fit through the end bells and frame and hold the entire motor together



ASSEMBLY BOLTS

9. **Types of motor construction**

   a. Motors are constructed for service in different applications and environments.

   b. Open motors have air openings in the frame and/or ends and are used where dirt, dust, and moisture are not a problem.

      Examples: Furnace blower motors and protected condenser fan motors.

   c. Open drip-proof motors have air openings in the frame with shrouds to prevent moisture from entering and are used where dripping moisture may be a problem.

      Example: Pump motors.

   d. Totally enclosed motors, not sealed, have no air openings and are used where dust, dirt, or moisture might be a problem.

      Example: Unprotected condenser fan motors.

   e. Explosion proof motors are constructed so that no sparking occurs and are used where explosive vapors are a problem.

      Example: Hermetic compressor motors.

   f. Submersible motors are totally enclosed and sealed and are used where it is necessary for the motor to be submersed in water or some other fluid.

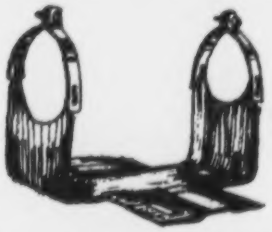
      Examples: Submersible pumps and hermetic compressor motors.

   g. A motor may be a single type or a combination of types, and an ACR technician must be able to recognize the different types and be able to select the appropriate type for a specific application.

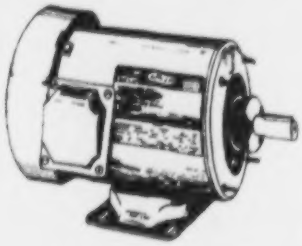
Information Sheet

10. **Types of motor mounts and typical applications**

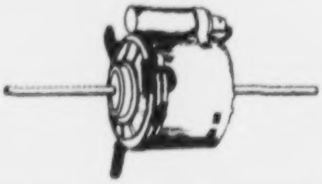
    a. **Cradle**—used on belt-drive blowers and window air conditioners



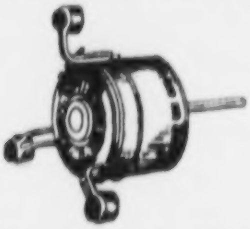
    b. **Rigid**—used on large belt-drive applications



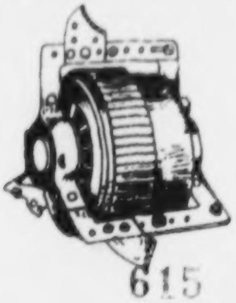
    c. **Lug-ring**—used on window air conditioners



    d. **Three-ring**—used on direct-drive blowers and window air conditioners



    e. **Blower frame**—used on direct-drive blowers



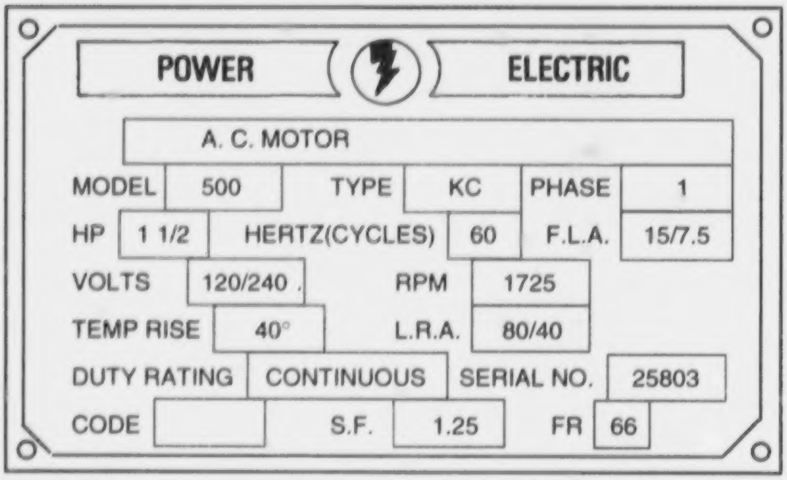
Information Sheet

11. **Motor data plates**

a. Most electric motors have information about the motor and its application somewhere on the motor.

b. Motor information usually is on a paper label or metal data plate although occasionally the information is stamped directly somewhere on the motor itself.

Typical Electric Motor Data Plate



POWER ELECTRIC

A. C. MOTOR

MODEL 500 TYPE KC PHASE 1

HP 1 1/2 HERTZ(CYCLES) 60 F.L.A. 15/7.5

VOLTS 120/240 RPM 1725

TEMP RISE 40° L.R.A. 80/40

DUTY RATING CONTINUOUS SERIAL NO. 25803

CODE S.F. 1.25 FR 66

c. Information provided on a typical motor data plate may include:

(1) the manufacturer's name, which may include the manufacturer of the equipment and the manufacturer of the motor,

(2) manufacturer's number, which may mean different things depending on the manufacturer,

(3) type of motor such as split-phase, shaded-pole, or other,

(4) model number,

(5) serial number,

(6) type, which is a coded designation using numbers or letters to indicate such things as type of motor and type of enclosure,

(7) horsepower rating, Hp.

Note: Multispeed motors sometimes give Hp rating for each speed.

Information Sheet

(8) voltage,

(9) phase, Ph,

(10) hertz (cycle),

(11) full load amperage, F.L.A., sometimes called rated load amperage or R.L.A.,

Note: If the motor is dual voltage, as in the data plate above, amperage ratings are given for both ratings; and if it is a multispeed motor, amperage ratings may be listed for each speed.

(12) locked rotor amperage, L.R.A.,

(13) revolutions per minutes, RPM, that a motor shaft turns,

(14) temperature rise, which is the allowable motor temperature increase and is usually indicated in degrees Celsius, °C,

(15) duty rating such as light, heavy, continuous,

(16) service factor, S.F.,

Example: An S.F. of 1.25 means a motor can be loaded 25% greater than its rated horsepower.

(17) frame, which is an NEMA designated number indicating the size of the body of the motor, and

(18) rotation which is normally designated by an arrow or CW for clockwise or CCW for counterclockwise.

Note: Some OEMs designate CW or CCW facing the shaft end of the motor, and some OEMs designate facing the end opposite the shaft end.

Information Sheet

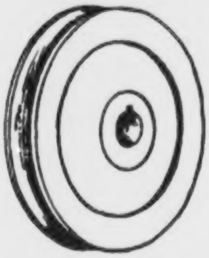
12. **Pulleys and belts**

a. Most motor applications are either direct drive with the motor shaft fastened directly to the load, or belt drive with V-pulleys and a belt connecting the motor shaft to the load.

b. V-pulleys, also called sheaves, come in three types:

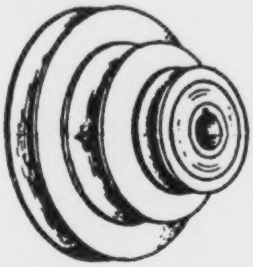
(1) standard pulleys with a single nonadjustable groove.

Standard Pulley



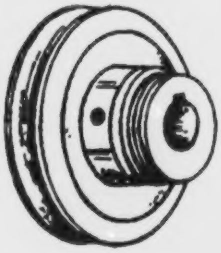
(2) step pulleys, which are like several standard pulleys fastened together.

Step Pulley

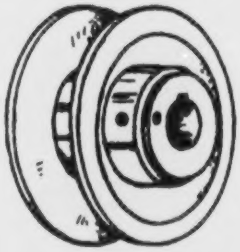


(3) adjustable pulleys, which can be adjusted to change the diameter of the pulley and/or the width of the groove.

Adjustable Pulley closed



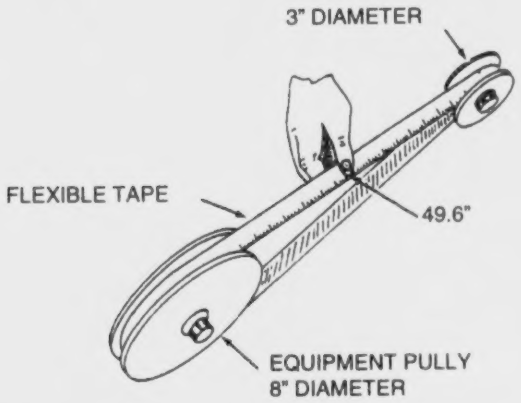
Adjustable Pulley open



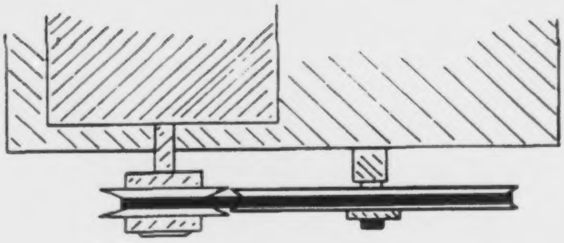
Information Sheet

c. A pulley on a motor is connected to a pulley on a load such as a blower by a V-belt which wraps around both pulleys.

d. The length of a V-belt is the distance around the outside of the belt, and the width is also measured at the outside, which is the widest part of the belt.


3" DIAMETER
FLEXIBLE TAPE
49.6"
EQUIPMENT PULLY
8" DIAMETER

e. It is important to select the proper belt and pulleys for each specific application, and to adjust the belt for the proper tension and alignment.



Information Sheet

13. Pulley selection

a. To select the proper pulley size requires knowing the motor rpm and the desired rpm of the load.

b. Pulley selection charts are available for motors of various rpm, and it is important to use a chart that matches the rpm of the motor.

Note: See Assignment Sheet 1 for a pulley selection chart for 1725 RPM motors and steps for using the chart properly.

c. If a pulley selection chart is not available, use the following pulley selection formula to select the proper pulley:

RPM of motor pulley x diameter of motor pulley = RPM of equipment pulley x diameter of equipment pulley.

Example: If you have a motor rated at 1725 RPM and a blower that has a 4" pulley and needs to turn at 2100 RPM, determine the size motor pulley needed by placing the known into the formula.

1725 x ? = 2100 x 4. To solve for the unknown, divide both sides of the equation by 1725.

$$\frac{1725 \times ?}{1725} = \frac{2100 \times 4}{1725} \text{ which gives } ? = \frac{8400}{1725} = 4.87"$$

So, the diameter of the motor pulley is 4.87"

d. Standard pulleys are normally available in 1/4" increments, so in the above example, you would have to use a 5" pulley or an adjustable pulley adjusted to 4.9".

Note: See Job Sheet 1 for the procedure to adjust an adjustable pulley.

Information Sheet

14. **Sizing and selecting V-belts**

    a. The first step in selecting a V-belt is to determine the width of belt needed.

    b. One of the two pulleys will nearly always be a standard pulley which can be measured by measuring across the top of the groove.

    c. V-belt widths come in 1/8" increments, and common sizes for belts used with ACR equipment are 3/8", 1/2", and 5/8".

    d. The next step in selecting a V-belt is to determine the length of belt needed.

       Note: See Job Sheet 1 for the procedure to determine the length of a V-belt.

    e. The numbers and letters on a V-belt indicate the size of the belt, but only if you know how to interpret them.

       Example: A belt labeled 4L380 is 1/2" wide x 38" long, and here is the way the 4L380 is interpreted: the first number 4 represents four 1/8" increments, or 4/8" which is 1/2". The L represents a particular style of V-belt, and the last three numbers are the length in decimal inches, 38.0", or 38".

    f. The final step is to select a belt designed for the kind of duty it will be subjected to; residential and industrial applications require different types of belts.

15. **Troubleshooting electric motors**

    a. Motor problems are either mechanical problems or electrical problems.

    b. Check for mechanical problems by visually examining parts, listening for unusual noises, and physically manipulating motor parts while looking, listening, and feeling.

    c. Check for electrical problems with electrical test instruments.

    d. Troubleshoot both mechanical and electrical problems by comparing responses to checks with expected responses using knowledge of how a motor is supposed to respond.

    e. Knowing how motors are supposed to respond is acquired through your own experience or other technicians' experiences recorded in troubleshooting guides.

       Note: See Student Supplement 1 and Assignment Sheet 2.

    f. Examine the motor you are troubleshooting and identify symptoms the motor exhibits.

Information Sheet

g. Rely on your own experience or use a troubleshooting chart such as the one in Student Supplement 1 to identify possible causes and remedies.

h. Use the following steps to apply the Open Drive Electric Motor Troubleshooting Chart:

   (1) locate the symptoms exhibited by the motor on the left hand side of the chart,

   (2) identify possible causes listed under the symptoms,

   (3) read across to the right of each cause to identify the checks needed to verify which causes need to be remedied, and

   (4) apply the listed remedies to repair the motor.

i. To complete any troubleshooting activity, check the motor start and run amps and compare them with data plate ratings.

Introduction to Electric Motors
Unit 8

Student Supplement 1—Open Drive Electric Motor Troubleshooting Chart

Symptoms & Possible Causes	**Checks and Remedies** **Note: Always check start and run amps after completing any remedy.**
1. Motor fails to start	
a. Low voltage or no voltage	Check supply voltage w/motor under load; if voltage is not within 10% of motor data plate voltage, correct at source.
b. Blown fuse at motor	Replace or reset fuse.
c. Incorrect line connections	Compare connections w/proper wiring diagram.
d. Open overload	Check overload w/ohmmeter; replace external overload if open.
e. Open motor wiring	Check motor wiring w/ohmmeter; replace winding or motor if open, shorted, or grounded.
f. Open start switch	Check switch continuity; if open, clean and adjust switch, or replace motor.
g. Start relay contacts fail to close	Check relay: replace if faulty
h. Open start or run capacitor	Disconnect and check capacitor; replace if necessary.
i. Excessive load	Remove load from motor and try to start motor; if motor starts and runs correctly, adjust load or use larger motor.
j. Excessive end play	
k. Worn or seized bearings	Move shaft by hand to check for end play, side play, and bearing tightness; adjust play or replace bearings as necessary.
2. Excessive noise	
a. Loose parts	Tighten loose accessories or mountings.
b. Belt slippage	Adjust belt tension and add belt dressing, if necessary.
c. Misaligned pulleys	Check alignment of drive pulley w/driven pulley; align as necessary.
d. Out-of-balance pulley	Replace out-of-balance pulley.
e. Bent shaft	Remove pulley and check straightness of shaft; replace motor.
f. Worn bearings	Move shaft by hand to check bearings; replace bearings or motor.
g. Debris in air gap between rotor and stator	Disassemble motor, inspect and clean if dirty.
h. Uneven air gap	Check roundness of rotor and inspect for worn place on rotor and stator.
3. Bearing overheating	
a. Bearings need oil	Oil bearings w/recommended nondetergent motor oil.
b. Dirty oil	Put clean oil in reservoir (if it is a large motor w/a reservoir).
c. Excessive grease	Clean excessive grease buildup from ball bearings.
d. Excessive belt tension	Adjust belt to proper tension and check w/an ammeter.
e. Excessive end thrust	Move shaft by hand to check for end play, side play, and bearing tightness; replace rough or worn bearings.
f. Excessive side play	
g. Rough bearing surface	
h. Bent shaft	Remove pulley and check for bent shaft; replace motor.
i. Pulleys misaligned	Check alignment of drive pulley w/driven pulley; align as necessary.

Introduction to Electric Motors
Unit 8

Student Supplement 1—Open Drive Electric Motor Troubleshooting Chart

Symptoms & Possible Causes	**Checks and Remedies**
4. Motor overheating	
a. Obstruction of ventilating system	Clean motor.
b. High ambient temperature location	Compare ambient temp w/mfg's recommendations: improve conditions as necessary.
c. Incorrect voltage	Check supply voltage w/motor under load; if voltage is not within 10% of motor data plate voltage, correct at source.
d. Excessive belt tension	Check belt tension; adjust as necessary.
e. Shorted run capacitor	Compare operating amperage to name plate FLA; if too high, disconnect, check capacitor, and replace if necessary.
f. Overloading	Compare operating amperage to name plate F.L.A.; reduce load or use larger motor.
g. Bearing problems	See Symptom 3.
5. Stator burned out	Rewind stator or replace motor. **Note:** The cause of this problem must be corrected to prevent failure of the replacement stator or motor.
a. Moisture	Check for a source of moisture, acids, alkalies, and conductive dust; provide motor protection as necessary.
b. Acids or alkalies	
c. Accumulation of excessive conductive dust	
d. Bearing problems	See Symptom 3.
e. Overloading	Check operating amperage after repair; reduce load or use larger motor.
f. Shorted start switch or run capacitor	Check start components; repair as necessary if reusing.

Introduction to Electric Motors
Unit 8

Assignment Sheet 1—Use a Pulley Selection Chart

Name ____________________ Overall Rating ________

Evaluation Criteria	**Rating**
Number of problems attempted	_____
Number of correct solutions	_____

Directions: Reference the Pulley Selection Chart that accompanies this assignment sheet to determine the pulley selection for the following applications.

> Sample problem: Given a motor speed of 1725 RPM and a blower with a 4" pulley that needs to turn at 2100 RPM, what size motor pulley is needed?
>
> Sample solution: Find equipment pulley size, 4", in the row at the top of the Pulley Selection Chart. Read down the column to find RPM reading equal to or greater than the equipment speed desired. In this case that is 2150. From the 2150 figure, follow the row straight across to the left and read the motor pulley size, 5".
>
> Note: Compare the solution to the solution found to this same problem in the example in Objective 13, using the pulley selection formula.

Problem A: Given a motor speed of 1725 RPM and a blower with an 8" pulley that needs to turn at 1050 RPM, what size motor pulley is needed?

Solution: ___________

Problem B: Given a motor speed of 1725 RPM and a blower with a 12" pulley that needs to turn at 1000 RPM, what size motor pulley is needed?

Solution: ___________

> Sample problem: Given a motor speed of 1725 RPM with a 3" motor pulley and a blower that needs to turn at 2100 RPM, what size blower pulley is needed?
>
> Sample solution: Locate motor pulley size, 3", in left hand column and read across in the row to the right and locate a speed that is equal to or greater than the equipment speed desired. In this case that is 2290. Follow the column straight up from the 2290 figure and read the equipment pulley size in the row at the top of the chart, 2 1/4".

Problem C: Given a motor speed of 1725 RPM with a 2" motor pulley and a blower that needs to turn at 800 RPM, what size blower pulley is needed?

Solution: ___________

Assignment Sheet 1

Pulley Selection Chart for 1725 RPM Motor

Equipment pulley diameter in inches with equipment pulley RPM shown below

Motor Pulley Diam. in Inches	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	3	4	5	6 1/2	8	10	12	15	18
1 1/4	1725	1435	1230	1075	950	850	715	540	430	330	265	215	—	—	—
1 1/2	2075	1725	1475	1290	1140	1030	850	645	515	395	320	265	215	—	—
1 3/4	2400	2000	1725	1500	1340	1200	1000	750	600	460	375	315	250	200	—
2	2775	2290	1970	1725	1530	1375	1145	850	685	530	430	345	285	230	—
2 1/4	3100	2580	2200	1930	1725	1550	1290	965	775	595	485	385	325	255	215
2 1/2	3450	2870	2460	2150	1900	1725	1435	1075	850	660	540	430	355	285	240
3	4140	3450	2950	2580	2290	2070	1725	1290	1070	800	615	515	430	345	285
4	5500	4575	3950	3450	3060	2775	2295	1725	1375	1060	860	700	575	460	375
5	6850	5750	4920	4300	3825	3450	2865	2150	1725	1325	1075	860	715	575	475
6 1/2	8950	7475	6400	5600	4975	4480	3730	2790	2240	1725	1400	1120	930	745	620
8	—	9200	7870	6900	6125	5520	4600	3450	2750	2120	1725	1375	1140	915	765
10	—	—	9850	8620	7670	6900	5750	4300	3450	2650	2150	1725	1430	1140	950
12	—	—	—	—	9200	8280	6900	5160	4130	3180	2580	2075	1725	1375	1140
15	—	—	—	—	—	—	8635	6470	5170	3970	3230	2580	2150	1725	1425
18	—	—	—	—	—	—	—	7750	6200	4770	3880	3100	2580	2070	1725

Introduction to Electric Motors
Unit 8

Assignment Sheet 2—Solve Electric Motor Problems

Name ______________________________ OverallRating _______

Evaluation Criteria	**Rating**
Number of scenarios attempted	_____
Number of correct solutions	_____

Directions: In the following scenarios, symptoms of electric motor problems and the results of initial checks are provided. Apply your own experience or consult Student Supplement 1 to solve each problem, and list remedies and any additional checks that need to be made.

Scenario A: Motor fails to start and an open circuit breaker was found.

Remedies and checks: ______________________________

Scenario B: Motor is overheating and the ventilation openings in the end bells were found to be clogged.

Remedies and checks: ______________________________

Scenario C: Motor is excessively noisy; shaft was found to have excessive side play.

Remedies and checks: ______________________________

Scenario D: Motor bearings are overheating; belt was found to have a 1/2" deflection.

Remedies and checks: ______________________________

Assignment Sheet 2

Scenario E: Motor used for belt drive is overheating; supply voltage is acceptable, run amps were found to be in excess of name plate rating, shaft side play, end play, and bearing tightness seemed acceptable.

Remedies and checks: ______________________________
____
____
____
____

Introduction to Electric Motors
Unit 8

Job Sheet 1—Replace a Missing V-Belt, Adjust Tension, and Check Motor Operation

Name ____ Attempt Number _______

Date ____ Overall Rating _______

Evaluation Criteria	Rating
Pulley alignment properly checked	_____
V-belt installed and tension properly checked	_____
Amperage checks made to verify proper operation	_____

A. Tools and equipment

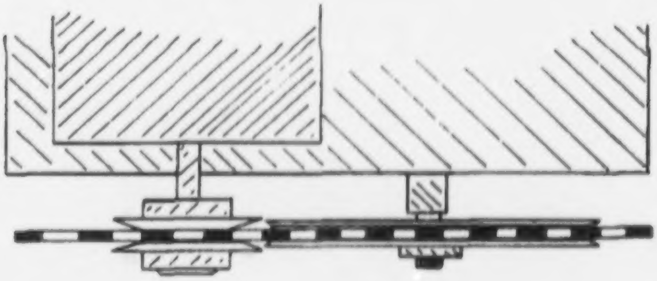
Belt-driven equipment with V-belt missing
Assorted V-belts for replacement selection
ACR technician's handtools
Straight edge
Tension gauge (optional)
Ammeter
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Disconnect electric power from the belt-driven equipment.

☐ 3. Check alignment of the pulleys with a straight edge that is narrower than the narrowest pulley groove.



☐ 4. If pulleys do not align, loosen set screws on one or both pulleys and realign them.

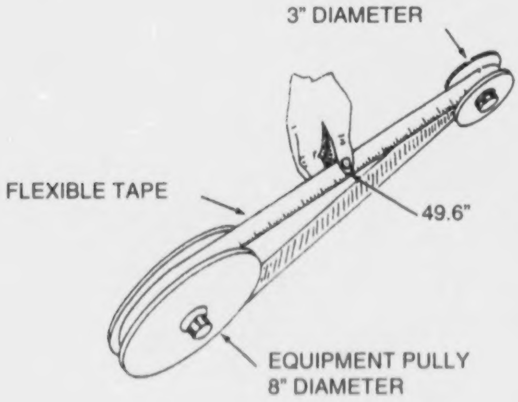
Job Sheet 1

☐ 5. Find belt tension adjustment which should move the motor and motor pulley toward and away from the load pulley, and adjust to the mid-point of the adjustment range.

Note: Adjustment is normally made by manipulating the motor mounting.

☐ 6. Measure the width of the groove on the load pulley to determine the width of the replacement belt.

☐ 7. Use a flexible measuring tape or a piece of flexible metal the same width as the belt will be, and wrap it around the pulleys just like the belt would fit to determine the replacement belt length.



☐ 8. Record your measurement here: ________________________.

☐ 9. Round the measurement off to the nearest full inch.

☐ 10. Have your instructor check your measurements.

☐ 11. Select a replacement V-belt.

☐ 12. Install the replacement V-belt with the following steps:

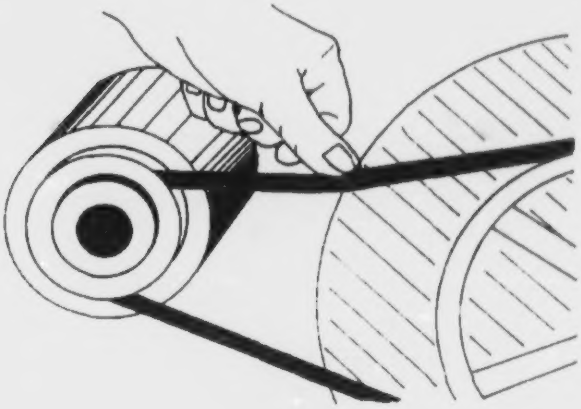
(1) Loop the belt onto the motor pulley.

(2) Start the belt onto one edge of the equipment pulley.

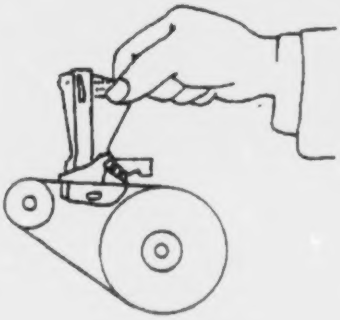
(3) Rotate the equipment pulley while pushing the belt onto the equipment pulley.

Job Sheet 1

☐ 13. Press against the V-belt halfway between the motor pulley and the equipment pulley.



☐ 14. Check for a deflection of 3/4" to 1", or use a tension gauge and the manufacturer's recommended tension setting.



☐ 15. Adjust tension as necessary.

☐ 16. Determine name plate amperage of motor and record here: FLA ____________________ LRA________________.

☐ 17. If the equipment is a blower unit, replace any panels because panels on blower compartment must be in place in order to obtain accurate amperage readings.

Note: Sometimes amperage readings must be obtained by reaching through panel openings; in those cases, the panels must be held in place as close as possible in order to duplicate operating air flow conditions.

Job Sheet 1

☐ 18. Start equipment and check motor start and run amperage. Draw and record them here:

Start amperage:____________; run amperage____________

☐ 19. Compare amperage readings to nameplate amperage: acceptable ☐; unacceptable ☐.

☐ 20. Have your instructor check your findings.

☐ 21. Adjust belt and air flow as necessary to obtain acceptable amperage draw.

☐ 22. Have your instructor check your work.

☐ 23. Disconnect power from equipment.

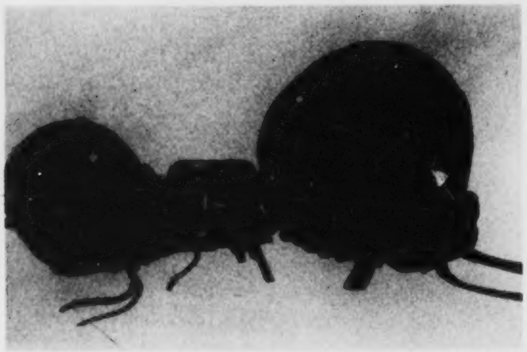
☐ 24. Clean up area and return tools and materials to proper storage.

Comments: ____

____

____

____



Shaded-Pole Motors

Unit 9

Objective Sheet

Unit Objective

After completing this unit, the student should be able to wire a shaded-pole motor for operation and disassemble, inspect, clean, reassemble, and check operation of a shaded-pole motor. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Complete statements about terms and definitions for shaded-pole motors.
2. Complete statements about characteristics and applications of shaded-pole motors.
3. Complete statements about shaded-pole motor construction.
4. Select true statements about controlling shaded-pole motor speed.
5. Solve problems about shaded-pole motor rotation.
6. Complete statements about troubleshooting shaded-pole motors.
7. Apply the power factor for watt/amp amp/watt conversion.
8. Wire shaded-pole motors to AC voltage. (Job Sheet 1)
9. Disassemble, inspect, clean, reassemble, and check operation of a shaded-pole motor. (Job Sheet 2)

Shaded-Pole Motors
Unit 9

Information Sheet

1. **Terms and definitions**

   a. **Reactor coil**—A coil of many turns of fine wire which is wired in series with the stator of a shaded-pole motor to provide a lower speed

   b. **Shading coil**—A closed loop of wire placed in a slot in the stator pole of a shaded-pole motor to provide a phase shift to aid in motor starting and to determine direction of rotation

2. **Characteristics and applications of shaded-pole motors**

   a. Shaded-pole motors are small, inexpensive, single phase motors with low torque.

   b. Shaded-pole motors come in either 120 VAC or 208/240 VAC, but not in either dual or three-phase voltages.

   c. Shaded-pole motors are not as efficient as most other types of motors, but their low cost makes them a good choice for many low torque applications.

   d. Shaded-pole motors are used in such applications as:

      (1) refrigerator evaporator fans,

      (2) refrigerator condenser fans,

      (3) small window air conditioner fans,

      (4) small furnace blowers,

      (5) furnace combustion fans, and

      (6) timers.

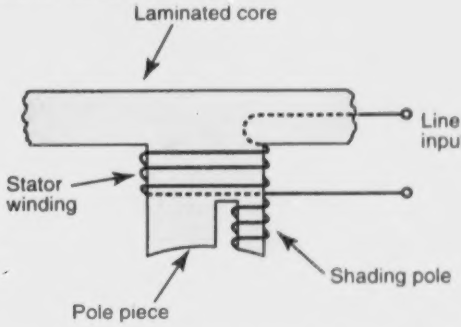
3. **Shaded-pole motor construction**

   a. Like all single-phase motors, shaded-pole motors must create a phase split which produces the two-phase current required to start the motor.

   b. Shaded-pole motors accomplish the phase split by using a shading coil.

Information Sheet

c. A shading coil is a portion of the stator winding wrapped around a separate portion of the laminated stator pole.


Laminated core
Line input
Stator winding
Shading pole
Pole piece

d. Each shading coil is a closed loop of wire wrapped through a slot in the stator pole.

e. The shading coil is located between the stator winding and the rotor.

f. The motor RPM is determined by the number of stator poles:

(1) two pole, 3,000 RPM,

(2) four pole, 1,500 RPM, and

(3) six pole, 1,050 to 1,100 RPM.

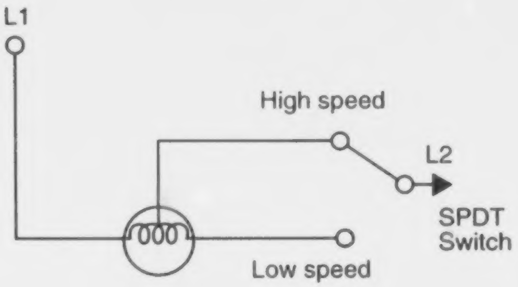
g. The speed of a shaded-pole motor may vary over a wide range with a change in either the load or the applied voltage.

4. **Controlling shaded-pole motor speed**

a. When shaded-pole motors are used in applications requiring more than one motor speed, the speed change is accomplished by using a tapped stator winding or a reactor coil.

b. With a tapped winding, the complete winding high resistance is used for low speed and a portion of the winding is used for each higher speed.

Tapped Winding

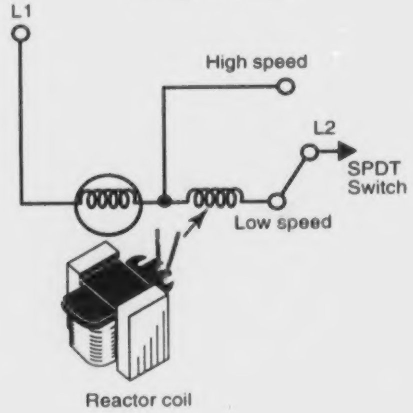

L1
High speed
L2
SPDT Switch
Low speed

Information Sheet

c. A reactor coil wired in series with the stator winding produces a lower speed than using the winding without the reactor coil.

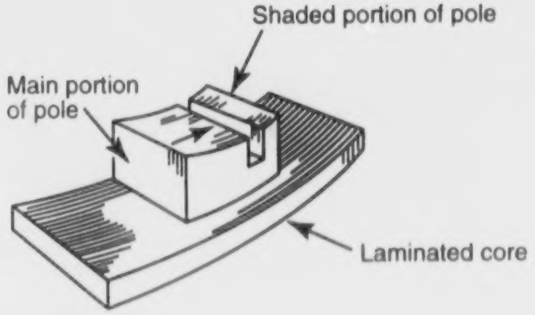
Note: Solid-state devices are sometimes used in place of a reactor coil.

Reactor in Circuit


L1
High speed
L2
SPDT Switch
Low speed
Reactor coil

5. **Shaded-pole motor rotation**

a. Shaded-pole motor rotation is determined by which side of the stator pole the shading slot is cut in.


Shaded portion of pole
Main portion of pole
Laminated core

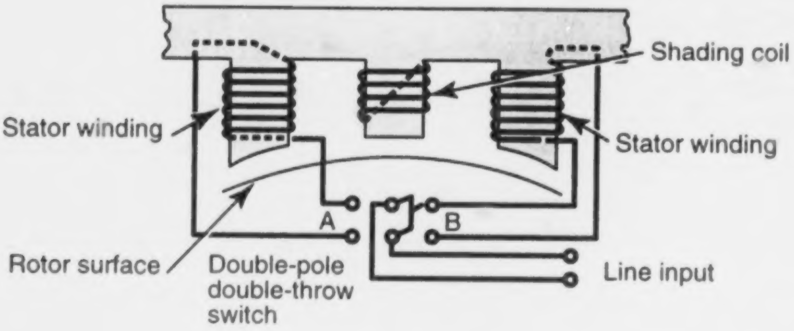
Note: Arrow on main portion of pole indicated direction of rotor rotation

b. Since it is not practical to change the location of slots in the stator pole, rotation cannot be changed unless electrical rotation reversal characteristics were built into the motor at the time of manufacture.

Information Sheet

c. Electrical reversal of rotation can be accomplished by including two shaded-pole stators within one frame, or dividing a single pole into subpoles.

One Pole of Laminated Core Cut into 3 Subpoles



With switch at A, rotation is clockwise
With switch at B, rotation is counterclockwise

d. Direction of rotation is determined by which set of leads are connected.

6. **Troubleshooting shaded-pole motors**

   a. Since most shaded-pole motors are small, time-consuming to disassemble, and relatively inexpensive, the generally accepted procedure is to replace rather than repair a shaded-pole motor that is having problems.

   b. Some shaded-pole motors are large enough to disassemble and clean or make minor repairs such as bearing replacement.

   c. Like all motors, shaded-pole motors will operate cooler and more efficiently when clean; air circulation openings in particular must not be blocked.

   d. Excessive end play or side play in the motor shaft are indications of problems with bearings, thrust washers, or spacers.

   e. Operating characteristics must be compared to name plate ratings to determine if the motor is operating within design parameters.

   f. Because many small motors are rated in full load watts instead of full load amps, a technician must either use a wattmeter or use watts law with the motor power factor, Pf, to convert the measured amp draw of the motor to watts or the data plate watts to amps for comparison.

Information Sheet

g. If a motor is clean, has no bearing problems, is receiving proper voltage, and still will not run or draws too much amperage, the motor should probably be replaced with a new motor.

Note: For additional troubleshooting assistance, see the Open Drive Electrical Motor Troubleshooting Chart in Unit 8.

7. Using power factor for watt/amp amp/watt conversions

a. The overlapping magnetic fields in inductive loads such as motors causes the real power used, watts, to be different from the apparent power used, volts times amps, VA.

b. The ratio of watts to VA is called the power factor, Pf, and is given as a decimal multiplier such as 0.75 or 0.80.

c. If the power factor of a motor is unknown, the general guideline is that the power factor for most small motors ranges from 0.60 to 0.80.

d. Watts law must be altered from $P = I \times E$ to $P = I \times E \times Pf$.

Example: Given a 120 VAC motor with a nameplate rating of 30W, the approximate expected amp draw of the motor can be calcuated as follows:

$$P = I \times E \times Pf$$
$$30 = I \times 120 \times .75$$
$$30 = I \times 90$$
$$\frac{30}{90} = \frac{I \times 90}{90}$$

$$0.33 = I \quad \text{or} \quad I = 0.33A$$

Shaded-Pole Motors
Unit 9

Job Sheet 1—Wire Shaded-Pole Motors to AC Voltage

Name ______________________________ Date _________ Attempt Number ____

Evaluation Criteria	**Rating**
Motor data plate information properly recorded	_____
Motor started for test readings	_____
Operating characterisitcs compared with data plate information	_____

A. Tools and materials

Assorted sizes of shaded-pole motors
Motor test cord or equivalent wiring
Analog ammeter w/10-wrap coil or digital ammeter
Wattmeter
Voltmeter
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Check with your instructor for any special instructions.

☐ 3. Select a large and a small motor from assorted motors supplied for this activity.

☐ 4. Record the following information from the motor data plate:

(a) manufacturer_________________________.

(b) model number____________________.

(c) serial number__________.

(d) type code__________________________.

(e) Hp___________.

(f) Volts________________________.

(g) Ph________________________.

(h) Hz____________________.

(i) F.L.A.___________.

(j) L.R.A.__________.

(k) RPM_______.

(l) Temp rise_____.

Job Sheet 1

(m) duty rating_____.

(n) S.F._____.

(o) frame_____.

(p) rotation_______, facing the shaft end: yes ☐, no ☐.

☐ 5. Connect motor leads to test cord or wiring.

☐ 6. Connect wattmeter according to meter instructions.

☐ 7. Place ammeter around one lead.

Note: If F.L.A. is less than 3A, use a digital ammeter or a 10-wrap coil to obtain accurate readings.

☐ 8. Connect test cord or wiring to appropriate voltage and start the motor.

☐ 9. Record start and run amps.

Start amps________; run amps_________.

☐ 10. Record start and run watts.

Start watts______; run watts______.

☐ 11. Compare readings to nameplate readings; acceptable ☐ unacceptable ☐.

☐ 12. Use Watt's Law to convert amp readings to watts and watt readings to amps in the space that follows.

Note: Refer to Objective 7 if you need assistance with the conversion process.

☐ 13. Have your instructor check all your findings.

☐ 14. Disconnect motor and wiring.

☐ 15. Clean up area and return tools and materials to proper storage.

Comments: ____

____

____

Shaded-Pole Motors
Unit 9

Job Sheet 2—Disassemble, Inspect, Clean, Reassemble, and Check Operation of a Shaded-Pole Motor

Name ______________________ Date _________ Attempt Number ____

Evaluation Criteria	**Rating**
Motor properly disassembled and cleaned	______
Motor parts inspected and end and side play checked	______
Motor electrical characteristics verified okay	______

A. Tools and materials

Assorted motors of different types
ACR technician's hand tools
Motor test cord
Ammeter w/10-wrap coil or digital ammeter
Wattmeter
Ohmmeter
Bench vise
Compressed air
Motor cleaning fluid
Shop rags
Sand cloth
Center punch or scratch awl
Soft-faced or rawhide hammer
Small socket set
Electric motor bearing oil
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Select from the motor assortment a shaded pole motor that was built to be disassembled.

Job Sheet 2

☐ 3. Record the following information from the motor data plate:

(a) manufacturer____________________________.

(b) model number_______________________.

(c) serial number___________.

(d) type code_____________________________.

(e) Hp____________.

(f) Volts____________________________.

(g) Ph____________________________.

(h) Hz_______________________.

(i) F.L.A.____________.

(j) L.R.A.___________.

(k) RPM________.

(l) Temp rise______.

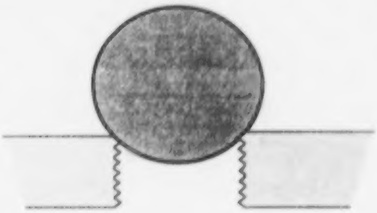
(m) duty rating______.

(n) S.F.______.

(o) frame______.

(p) rotation________, facing the shaft end: yes ☐, no ☐.

☐ 4. Open the bench vise almost wide enough for the motor to fit between the jaws, and place the motor across the opening in the jaws.



Job Sheet 2

☐ 5. Clean the motor with compressed air.

CAUTION: Always use compressed air with extreme care because it can turn objects into missiles that fly through the air at great speed and pose a danger to people and property.

☐ 6. Clean off outer surface of motor with rags and cleaning fluid as needed.

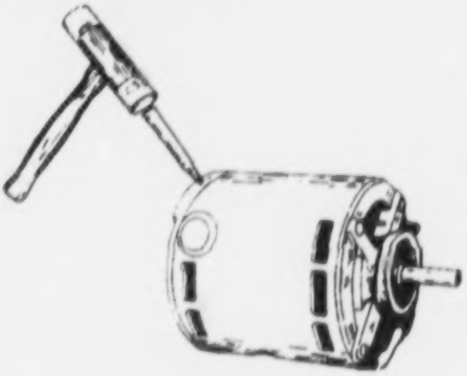
☐ 7. Clean the shaft or shafts with cleaning fluid and sand cloth as necessary.

☐ 8. Grasp motor shaft and check side play: acceptable ☐, unacceptable ☐; and end play: acceptable ☐, unacceptable ☐.

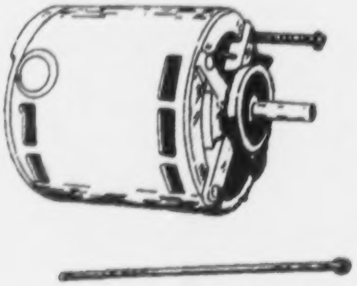
☐ 9. Have your instructor verify your findings.

☐ 10. Remove fan blade, if present, and clean and polish the shaft where the fan blade was secured.

☐ 11. Use a center punch or a scratch awl to mark the end bells and the motor body with marks that can be used to realign the end bells and the body when the motor is reassembled.

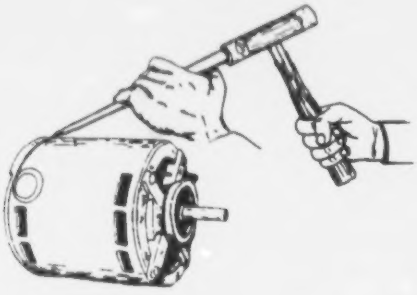


☐ 12. Remove the bolts holding the end bells to the housing.



Job Sheet 2

☐ 13. Use a soft-faced hammer and punch or awl to tap the end bells loose.



☐ 14. Remove end bells, and observe presence and position of any washers, shims, or spacers on the shaft.

☐ 15. Remove rotor.

☐ 16. Clean motor parts with compressed air.

☐ 17. Check to see if bearing wicks are full of oil by pushing on the wicks with your finger or a small screwdriver.

☐ 18. If no oil appears when wicks are pressed, soak wicks in oil.

Note: Use SAE 20 nondetergent oil if motor specifications are unknown.

☐ 19. Clean bearings.

CAUTION: Do not clean ball bearings with compressed air.

☐ 20. Check stator and rotor and shaft for signs of wear and misalignment.

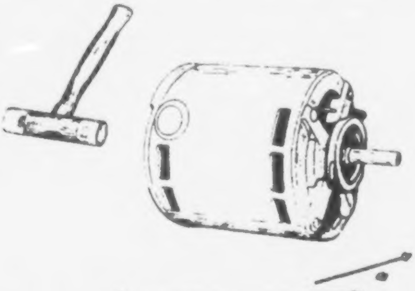
Note: If new bearings are needed and there are no other signs of problems, the new bearings would be installed at this time.

☐ 21. Oil shaft or shafts lightly.

☐ 22. Insert rotor and replace end bells loosely, making sure that all washers, spacers, or shims are in their proper place.

☐ 23. Align marks on end bells with marks on body.

☐ 24. Use soft-faced hammer to tap end bells into place.



Job Sheet 2

☐ 25. Insert assembly bolts and tighten single bolts on opposite sides snugly at first and then tighten the other bolts, and then tighten the first two.

☐ 26. Turn the motor shaft by hand and check side play and end play.

☐ 27. If shaft is tight, loosen bolts and realign until the shaft turns properly.

☐ 28. Replace the fan blade, if you removed it.

☐ 29. Have your instructor inspect your assembly.

☐ 30. Use ohmmeter to check resistance of winding or windings, and record readings:

#1__________ #2________ #3________

☐ 31. Use ohmmeter readings to determine motor speed connections.

High speed, leads ________ and _________.
Medium speed, leads ________ and _________.
Low speed, leads _______ and _________.

☐ 32. Have your instructor inspect your findings.

☐ 33. Connect test cord to high speed motor leads.

☐ 34. Record FLA from motor data plate: ___________.

☐ 35. Clamp ammeter around one motor lead or connect wattmeter.

Note: If FLA is less than 3A, a 10-wrap coil must be used with most analog ammeters.

☐ 36. Connect test cord to power.

☐ 37. Record start amps: __________ and run amps: ________.

☐ 38. Compare amp readings to FLA: acceptable ☐ not acceptable ☐.

☐ 39. Have your instructor check your findings.

☐ 40. Clean up area and return tools and materials to proper storage.

Comments: ____

____

____

Split-Phase Motors

Unit 10

Objective Sheet

Unit Objective

After completing this unit, the student should be able to wire a split-phase motor to an AC power source; wire a dual-voltage, split-phase motor for 120 VAC and for 208/240 VAC; and disassemble, inspect, reassemble, and check operations of a split-phase motor. The student should demonstrate these competencies by completing the activities in the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objecives

After completing this unit, the student should be able to:

1. Complete statements about terms and definitions for split-phase motors.
2. Complete statements about characteristics and applications of split-phase motors.
3. Complete statements about split-phase motor construction.
4. Complete statements about split-phase motor starting mechanisms.
5. Complete statements about wiring connections for split-phase motors.
6. Complete statements about troubleshooting split-phase motors.
7. Wire a single-voltage, split-phase motor to an AC power source. (Job Sheet 1)
8. Wire a dual-voltage, split-phase motor for 120 VAC. (Job Sheet 2)
9. Wire a dual-voltage, split-phase motor for 208/240 VAC. (Job Sheet 3)
10. Disassemble, inspect, clean, reassemble, and check operation of a split-phase motor. (Job Sheet 4)

Split-Phase Motors
Unit 10

Information Sheet

1. **Terms and definitions**

    a. **Start winding**—The stator winding that is used for starting an electric motor

    b. **Run winding**—The stator winding that is used continuously during normal operations of an electric motor

2. **Characteristics and applications of split-phase motors**

    a. Split-phase motors are small to medium size, relatively low-cost, single-phase motors with low to medium torque.

    b. Split-phase motors commonly range from 1/20 to 3/4 Hp.

    b. Split-phase motors come in either 120 VAC or 208/240 VAC, and in dual voltage that can be connected to either 120 VAC or 208/240 VAC.

    c. Split-phase motors are used in such applications as:

        (1) small to medium-size direct-drive fans and blowers,

        (2) pumps,

        (3) belt-drive blowers,

        (4) refrigerator and freezer compressors, and

        (5) small, commercial refrigeration hermetic compressors.

Information Sheet

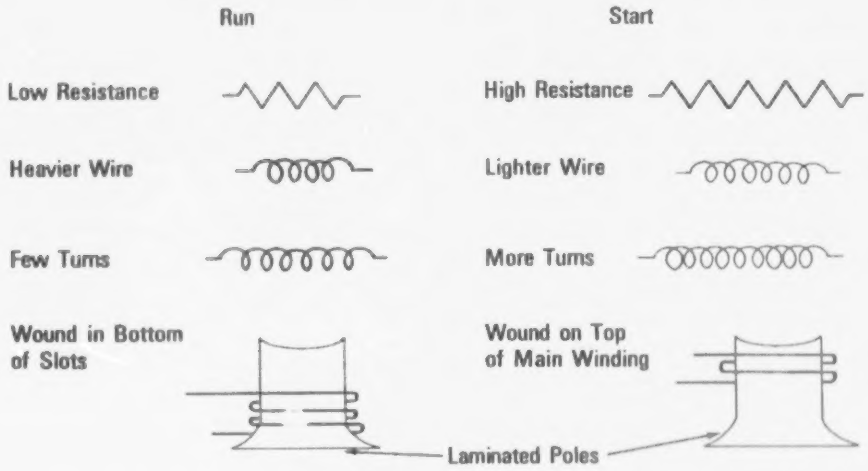
3. Split-phase motor construction

a. Like all single-phase motors, split-phase motors must create a phase split which produces the two-phase current required to start the motor.

b. Split-phase motors accomplish the phase split by using two stator windings, a start winding and a run winding.

c. Making the start winding longer and out of lighter-gauge wire means it will have more resistance than the run winding.

Characteristics of Start and Run Windings


Run
Start
Low Resistance
High Resistance
Heavier Wire
Lighter Wire
Few Turns
More Turns
Wound in Bottom of Slots
Wound on Top of Main Winding
Laminated Poles

d. When current is applied to both windings at the same time, current through the start winding will lead current running through the run winding.

e. The rotor will be attracted to the start winding pole a little sooner than to the run winding pole, and this attraction provides starting torque.

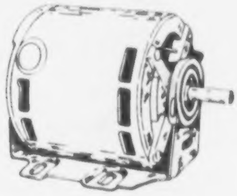
f. Because of its lighter construction, the start winding will burn up if it is left in the circuit longer than a few seconds.

g. A starting mechanism is used to remove the start winding from the circuit when the motor reaches approximately 75% to 80% of its rated speed.

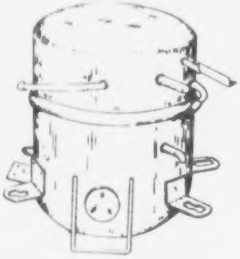
h. Split-phase motors used in ACR applications are usually single-speed motors.

Information Sheet

i. Split-phase motors used in ACR applications are either open-drive construction or hermetic construction.



Open Drive Motor



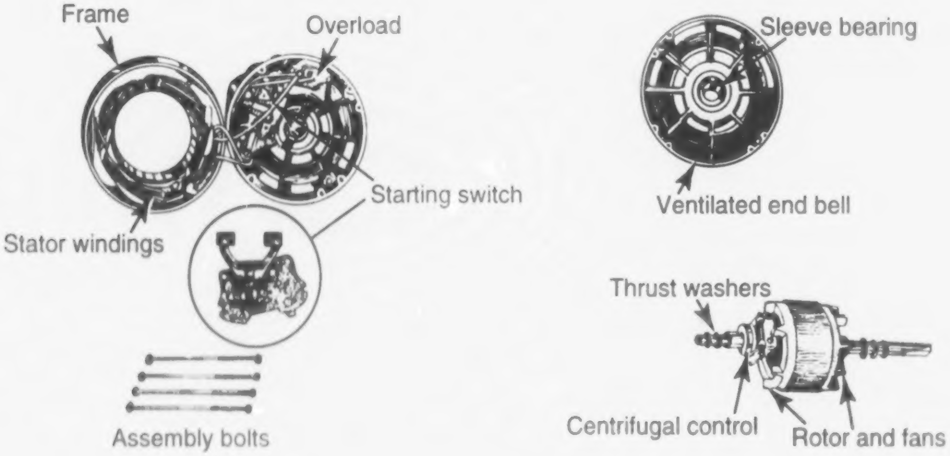
Hermetic Motor

4. Split-phase motor starting mechanisms

a. The element that differentiates the split-phase motor from other single-phase AC motors is the type of starting mechanism required.

b. Despite their names, starting mechanisms do not "start" motors; their main function is to disconnect starting components.

c. Open-drive motors use centrifugal controls or other mechanical means as start mechanisms.

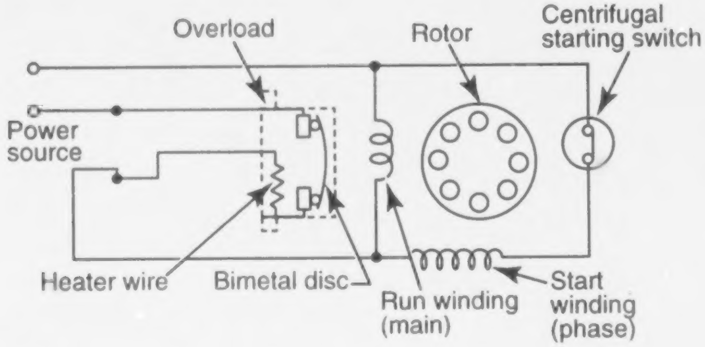

Frame
Overload
Starting switch
Stator windings
Assembly bolts
Sleeve bearing
Ventilated end bell
Thrust washers
Centrifugal control
Rotor and fans

d. Hermetic motors use starting relays because motor starting components must be external; if the devices were internal, arcing points would ignite refrigeration oil.

Information Sheet

5. Wiring connections for split-phase motors

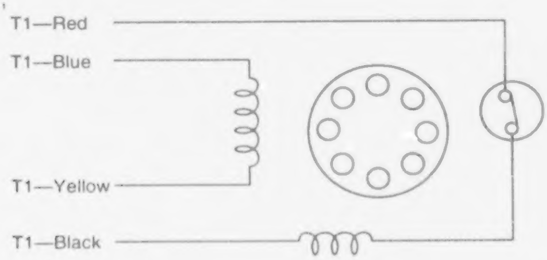
a. The normally closed centrifugal starting switch on open-drive split-phase motors is wired in series with the start winding and opens when the motor reaches approximately 75% to 80% of its rated speed.


Overload
Rotor
Centrifugal starting switch
Power source
Heater wire
Bimetal disc
Run winding (main)
Start winding (phase)

b. There is usually an overload connected in series with one leg of the power.

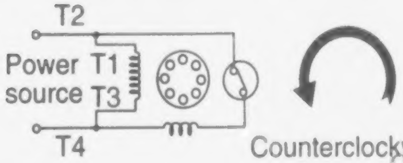
c. The overload contains a bimetal disc which opens the circuit when it overheats due to high motor temperature or high current causing the heater wire to heat up.

d. There are standard NEMA color codes for split-phase motor start and run winding connections.

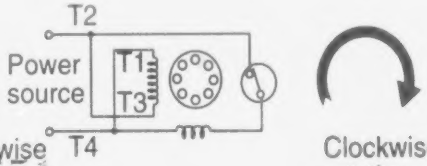

T1—Red
T1—Blue
T1—Yellow
T1—Black

e. On motors designed for rotation reversal, the rotation can be changed by reversing the leads.

CAUTION: Attempting to reverse motors not designed to be reversed will usually damage the motor.


T2
Power source
T1
T3
T4

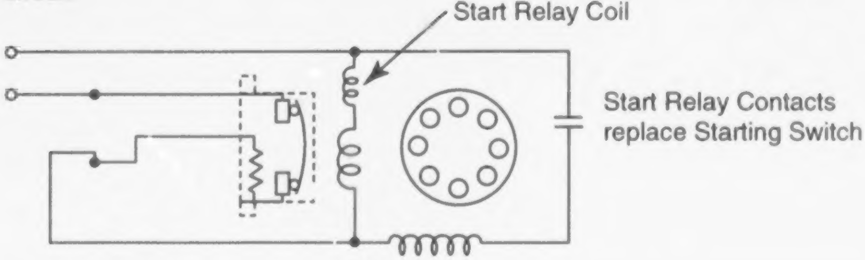
Counterclockwise rotation


T2
Power source
T1
T3
T4

Clockwise rotation

Information Shee

f. Hermetic split-phase motor wiring has the addition of a start relay coil in the circuit.



g. Start relay contacts are open initially, close in response to high starting current, and open again in response to lower operating current.

6. Troubleshooting split-phase motors

a. Open-drive split-phase motors can usually be disassembled for cleaning and some repairs.

b. Like all motors, open-drive split-phase motors will operate cooler and more efficiently when clean; air circulation openings in particular must not be blocked.

c. Excessive end play or side play in the motor shaft are indications of problems with bearings, thrust washers, or spacers.

d. In a split-phase motor, the components which most often give problems are the starting components.

e. The centrifugal control or the switch or relay contacts may stick open or shut, causing the motor not to start or the start windings to remain engaged and burn up.

f. Start relay coils may open causing the motor not to start because contacts will not close

g. Mechanical problems can sometimes be repaired, but electrical problems such as open or grounded windings usually require replacing the motor.

h. Faulty overloads can sometimes be replaced or may be jumpered for temporary duty.

Note: For additional troubleshooting assistance, see the Electrical Motor Troubleshooting Chart in Unit 8.

Split-Phase Motors
Unit 10

Job Sheet 1—Wire a Single-Voltage, Split-Phase Motor to an AC Power Source

Name____ Attempt Number______
Date____ Overall Rating _______

Evaluation Criteria	**Rating**
All available data plate information recorded	_____
Start and run windings accurately identified	_____
Start and run amps checked and evaluated	_____

A. Tools and materials

Single voltage split-phase motor w/centrifugal start switch and w/no internal components connected, but connections accessible for external wiring
Motor test cord or equivalent wiring
AC technician's hand tools
Ammeter
Voltmeter
Ohmmeter
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Check with your instructor for any special instructions.

☐ 3. Stabilize the motor so it will not move when running.

☐ 4. Record the following information from the motor data plate:

(a) manufacturer__________________________.

(b) model number_____________________.

(c) serial number__________.

(d) type code___________________________.

(e) Hp___________.

(f) Volts________________________.

(g) Ph________________________.

Job Sheet 1

(h) Hz______________________.

(i) F.L.A.____________.

(j) L.R.A.___________.

(k) RPM________.

(l) Temp rise_____.

(m) duty rating_____.

(n) S.F._____.

(o) frame_____.

(p) rotation_________; facing shaft end, yes ☐, no ☐.

☐ 5. Identify which external leads or connections connect to which internal components.

☐ 6. Use ohmmeter to determine which winding is run and which is start; the start winding will have higher resistance.

☐ 7. Connect test cord or wiring to appropriate voltage.

☐ 8. Place ammeter around one lead and start the motor.

☐ 9. Record start and run amps.

Start amps________; run amps_________.

☐ 10. Compare readings to nameplate readings; acceptable ☐, unacceptable ☐.

☐ 11. Listen for centrifugal start switch to open as the motor starts and for the switch to close as motor stops.

☐ 12. Have your instructor check all your findings.

☐ 13. Disconnect motor and wiring.

☐ 14. Clean up area and return tools and materials to proper storage.

Comments:____

____

____

Split-Phase Motors
Unit 10

Job Sheet 2—Wire a Dual-Voltage, Split-Phase Motor for 120 VAC

Name____ Attempt Number______
Date____ Overall Rating _______

Evaluation Criteria	**Rating**
All available data plate information recorded	_____
Run winding and start windings accurately identified	_____
Start and run amps checked and evaluated	_____

A. Tools and materials

Dual-voltage split-phase motor w/centrifugal start switch and w/no internal components connected, but connections accessible for external wiring
Motor test cord or equivalent wiring
AC Technician's hand tools
Ammeter
Voltmeter
Ohmmeter
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Check with your instructor for any special instructions.

☐ 3. Stabilize the motor so it will not move when running.

☐ 4. Record the following information from the motor data plate:

(a) manufacturer__________________________.

(b) model number______________________.

(c) serial number__________.

(d) type code___________________________.

(e) Hp___________.

(f) Volts_________________________.

(g) Ph_________________________.

Job Sheet 2

(h) Hz____________________.

(i) F.L.A.___________.

(j) L.R.A.___________.

(k) RPM_______.

(l) Temp rise_____.

(m) duty rating_____.

(n) S.F._____.

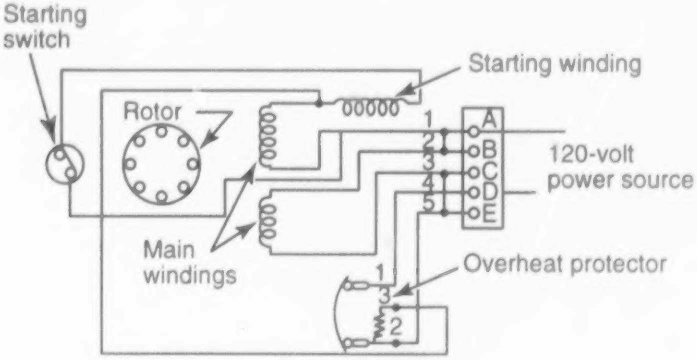
(o) frame_____.

(p) rotation_________; facing shaft end, yes ☐, no☐.

☐ 5. Identify which external leads or connections connect to which internal components.

☐ 6. Use ohmmeter to determine which windings are the two run windings and which winding is the start winding.

☐ 7. Wire motor components according to the following diagram or OEM diagram if available.


Starting switch
Starting winding
Rotor
1
2
3
4
5
A
B
C
D
E
120-volt power source
Main windings
Overheat protector
1
3
2

☐ 8. Connect test cord or wiring to 120VAC power supply.

☐ 9. Place ammeter around one lead and start the motor.

☐ 10. Record start and run amps.

Start amps________; run amps_________.

Job Sheet 2

☐ 11. Compare readings to nameplate readings; acceptable ☐, unacceptable☐.

☐ 12. If current draw is much higher than nameplate, run windings may be competing with one another, a condition sometimes called "bucking", so reverse the connections on either run winding.

☐ 13. Restart motor and record start and run amps.

Start amps_______: run amps_______.

☐ 14. Compare readings to nameplate readings: acceptable ☐, unacceptable ☐.

☐ 15. Have your instructor check all your findings.

☐ 16. Disconnect motor and wiring.

☐ 17. Clean up area and return tools and materials to proper storage.

Comments:____

____

____

Split-Phase Motors
Unit 10

Job Sheet 3—Wire a Dual-Voltage, Split-Phase Motor for 208/240 VAC

Name______________________________ Attempt Number______
Date______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
All available data plate information recorded	_____
Start and run windings accurately identified	_____
Start and run amps checked and evaluated	_____

A. Tools and materials

Dual-voltage split-phase motor w/centrifugal start switch and w/no internal components connected, but connections accessible for external wiring
Motor test cord or equivalent wiring
AC technician's hand tools
Ammeter
Voltmeter
Ohmmeter
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Check with your instructor for any special instructions.

☐ 3. Stabilize the motor so it will not move when running.

☐ 4. Record the following information from the motor data plate:

(a) manufacturer__________________________.

(b) model number_____________________.

(c) serial number__________.

(d) type code___________________________.

(e) Hp__________.

(f) Volts________________________.

(g) Ph________________________.

(h) Hz____________________.

(i) F.L.A.____________.

(j) L.R.A.____________.

(k) RPM________.

(l) Temp rise_____.

(m) duty rating_____.

(n) S.F._____.

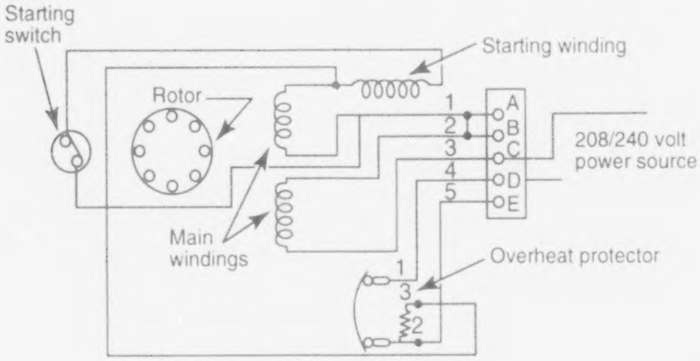
(o) frame_____.

(p) rotation_________; facing shaft end, yes ☐, no ☐.

☐ 5. Identify which external leads or connections connect to which internal components.

☐ 6. Use ohmmeter to determine which windings are the two run windings and which winding is the start winding.

☐ 7. Wire motor components according to the following diagram or OEM diagram if available.


Starting switch
Starting winding
Rotor
1
2
3
4
5
A
B
C
D
E
208/240 volt power source
Main windings
Overheat protector
1
3
2

☐ 8. Connect test cord or wiring to 208/240 VAC power supply.

☐ 9. Place ammeter around one lead and start the motor.

☐10. Record start and run amps.

Start amps________; run amps_________.

Job Sheet 3

☐ 11. Compare readings to nameplate readings; acceptable ☐, unacceptable ☐.

☐ 12. Have your instructor check all your findings.

☐ 13. Disconnect motor and wiring.

☐ 14. Clean up area and return tools and materials to proper storage.

Comments: ____

____

____

Split-Phase Motors
Unit 10

Job Sheet 4—Disassemble, Inspect, Clean, Reassemble, and Check Operation of a Split-Phase Motor

Name________________________________ Attempt Number______
Date________________________________ Overall Rating _______

Evaluation Criteria	Rating
All available data plate information recorded	_____
Parts inspected and cleaned or replaced as required	_____
Start and run amps checked and evaluated	_____

A. Tools and materials

Assorted motors of different types
ACR technician's hand tools
Motor test cord
Ammeter
Ohmmeter
Bench vise
Compressed air
Motor cleaning fluid
Shop rags
Sand cloth
Extra fine sandpaper
Center punch or scratch awl
Soft-faced or rawhide hammer
Small socket set
Electric motor bearing oil
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Select split-phase motor from motor assortment.

☐ 3. Record the following information from the motor data plate:

(a) manufacturer__________________________.

(b) model number_____________________.

(c) serial number__________.

(d) type code___________________________.

Job Sheet 4

(e) Hp____________.

(f) Volts____________________________.

(g) Ph____________________________.

(h) Hz________________________.

(i) F.L.A.____________.

(j) L.R.A.___________.

(k) RPM________.

(l) Temp rise______.

(m) duty rating______.

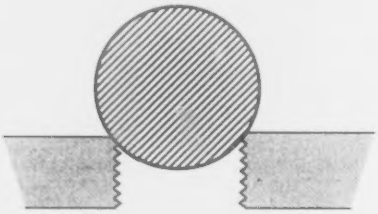
(n) S.F.______.

(o) frame______.

(p) rotation__________; facing shaft end, yes ☐, no ☐.

☐ 4. Open the bench vise almost wide enough for the motor to fit between the jaws.

☐ 5. Place the motor across the opening in the jaws.



☐ 6. Clean the motor with compressed air.

CAUTION: Always use compressed air with extreme care because it can turn objects into missiles that fly through the air at great speed and pose a danger to people and property.

☐ 7. Clean off outer surface of motor with rags and cleaning fluid as needed.

☐ 8. Clean the shafts or shafts with cleaning fluid and sand cloth as necessary.

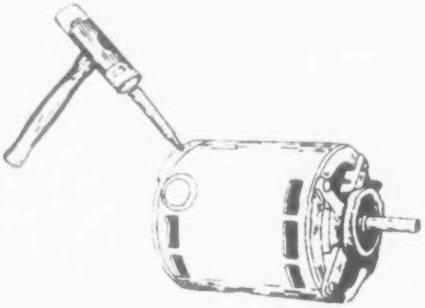
Job Sheet 4

☐ 9. Take hold of motor shaft and check side play: acceptable ☐, unacceptable ☐ , and end play: acceptable ☐, unacceptable ☐.

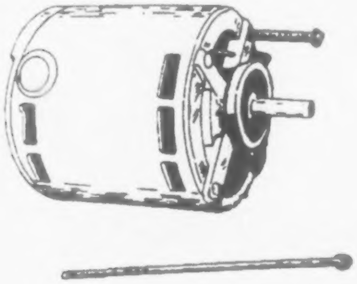
☐ 10. Have your instructor verify your findings.

☐ 11. Remove pulley, if present, and clean and polish the shaft where the pulley was secured.

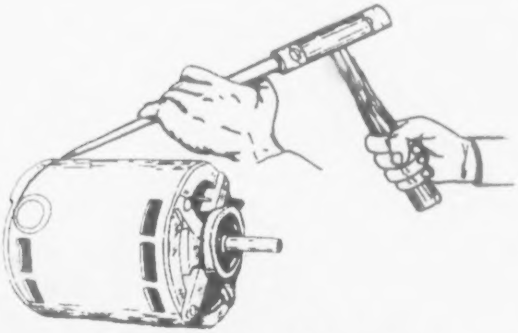
☐ 12. Use a center punch or a scratch awl to mark the end bells and the motor body with marks that can be used to realign the end bells and the body when the motor is reassembled.



☐ 13. Remove the bolts holding the end bells to the housing.



☐ 14. Use a soft-faced hammer and punch or awl to tap the end bells loose.



Job Sheet 4

☐ 15. Remove end bell that does not contain the starting switch, and observe presence and position of any washers, shims, or spacers on the shaft.

☐ 16. Remove rotor.

☐ 17. Remove end bell containing starting switch.

Note: The end bell will come loose from the frame, but may not be totally removeable because of the connecting wires.

☐ 18. Clean motor parts with compressed air.

☐ 19. Check to see if bearing wicks are full of oil by pushing on the wicks with your finger or a small screwdriver.

☐ 20. If no oil appears when wicks are pressed, soak wicks in oil.

Note: Use SAE 20 nondetergent oil if motor specifications are unknown.

☐ 21. Clean bearings.

CAUTION: Do not clean ball bearings with compressed air.

☐ 22. Check stator and rotor and shaft for signs of wear and misalignment.

Note: If new bearings are needed and there are no other signs of problems, the new bearings would be installed at this time.

☐ 23. Check centrifugal switch control on the rotor for wear and ease of movement.

☐ 24. Check centrifugal swtich contacts and clean with extra fine sandpaper, if necessary.

☐ 25. Make sure the switch components are in proper position and not bent or out of alignment.

☐ 26. Oil shaft or shafts lightly.

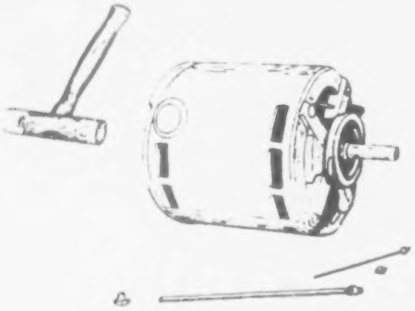
☐ 27. Replace end bell with start switch in it.

☐ 28. Insert rotor and replace other end bell loosely, making sure that all washers, spacers, or shims are in their proper place.

☐ 29. Align marks on end bells with marks on body.

Job Sheet 4

☐ 30. Use soft-faced hammer to tap end bells into place.



☐ 31. Insert assembly bolts and tighten single bolts on opposite sides snugly at first and then tighten the other bolts, and then tighten the first two.

☐ 32. Turn the motor shaft by hand and check side play and end play.

☐ 33. If shaft is tight, loosen bolts and realign until the shaft turns properly.

☐ 32. Have your instructor inspect your assembly.

☐ 33. Use ohmmeter to check resistance of windings, and record readings:

#1__________ #2________ #3________

☐ 34. Use ohmmeter to check if start switch is closed as it should be: closed ☐, open ☐.

☐ 35. If start switch is open, disassemble motor and realign components as necessary.

☐ 36. Reassemble motor and recheck start switch: closed ☐, open ☐.

☐ 37. Have your instructor inspect your findings.

☐ 38. Connect test cord to motor leads.

☐ 39. Clamp ammeter around one motor lead.

☐ 40. Connect test cord to appropriate power supply.

☐ 41. Record start amps:__________ and run amps:________.

☐ 42. Compare amp readings to FLA: acceptable ☐, not acceptable ☐.

☐ 43. Have your instructor check your findings.

☐ 44. Clean up area and return tools and materials to proper storage.

Comments: ______________________________________

Capacitors

Unit 11

Objective Sheet

Unit Objective

After completing this unit, the student should be able to calculate ratings of grouped capacitors, check capacitors with an analog ohmmeter, and check capacitors with a capacitor analyzer. The student should demonstrate these competencies by completing the activities in the assignment and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to capacitors with their correct definitions.
2. Select true statements about capacitors in ACR circuit applications.
3. Complete statements about effects of inductive loads on current/voltage relationships.
4. Solve problems about capacitor construction and operation.
5. Complete statements about types of capacitors.
6. Apply guidelines for capacitor replacement.
7. Complete statements about grouping capacitors.
8. Calculate ratings of grouped capacitors. (Assignment Sheet 1)
9. Check capacitors with an analog ohmmeter. (Job Sheet 1)
10. Check capacitors with a capacitor analyzer. (Job Sheet 2)

Capacitors
Unit 11

Information Sheet

1. **Terms and definitions**

   a. **Capacitance**—The factor in an electrical circuit that allows for temporary storage of electrical charges and opposes any change in existing voltage

   b. **Capacitor**—A device that uses parallel metal plates or foil separated by a dialectric which allows alternating current to flow and creates capacitance in a circuit; it is also called a condenser

   c. **Dialectric**—A substance such as air or mica that is a nonconductor of direct current

   d. **Inductance**—The phenomena whereby AC voltage is induced in a wire when the wire is located within the magnetic field created by current flow

   e. **Impedance**—The combined effect of resistance and reactance or the total opposition to the flow of alternating current in an electrical circuit

   f. **Reactance**—The opposition to current flow caused by the combined effect of inductance or capacitance and the frequency of alternating current

2. **Capacitors in ACR circuit applications**

   a. Capacitors are used with several types of single-phase motors to create a phase shift or split which produces the two-phase current required to start single-phase motors.

   b. The presence of a capacitor in an inductive circuit tends to cancel out the effect of the inductive load on the current/voltage relationship.

   c. Two inductive coils on separate branches of an AC circuit, one with and one without a capacitor, will each have a different current/voltage relationship.

   d. When two coils, one with and one without a capacitor, are placed in a motor, they will be out of phase with each other when AC voltage is applied, and this creates starting torque.

Information Sheet

3. **Effects of inductive loads on current/voltage relationships**

   a. When alternating current flows through wire arranged in a coil, current is induced in the adjacent turns of the coil because the magnetic field of each turn is cutting across the wire in the adjacent turns.

   b. The self-induced voltge opposes the current that is causing the magnetic field to build up; therefore, inductance opposes any change in current flow.

   c. The frequency of the alternating current affects the strength of the magnetic field and therefore affects the strength of the opposition to current flow.

   d. The combined effect of the two factors, inductance and frequency, is called inductive reactance.

   e. In a capacitive circuit, the combined effect of capacitance and frequency is called capacitive reactance.

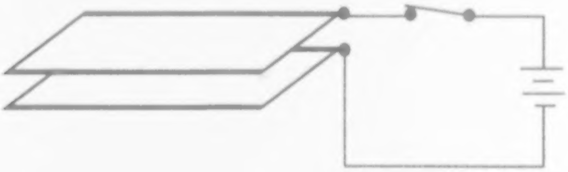
   f. The combined opposition of reactance and resistance is called impedance which is the total opposition to current flow.

   g. In inductive loads like motors, self-induction causes current to lag behind voltage.

4. **Capacitor construction and operation**

   a. Capacitors contain two metal plates, placed close to one another but not touching.

   b. In a capacitive circuit, the two plates are connected to a power source through a switch.



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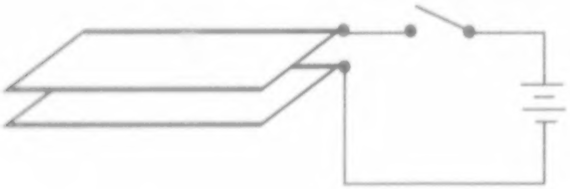
   c. At the instant the switch is closed, electrons are attracted from one plate to the positive terminal of the battery, and an equal number of electrons are repelled into the other plate from the negative terminal of the battery.

Information Sheet

d. When the switch is opened, one plate is left with a deficiency of electrons and the other plate has an excess of electrons creating a potential difference.



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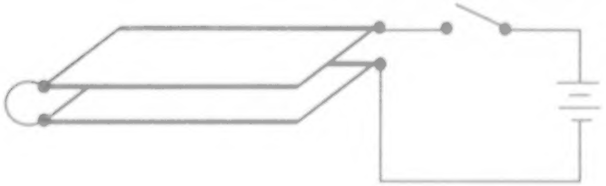
e. If we touch a jumper between the two plates, a temporary electron flow takes place until electrical balance between the plates is restored.



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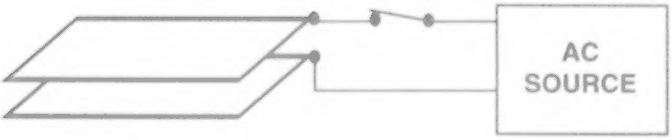
f. The capacitor is charged when the switch is closed, electrons are stored when the switch is opened, and electrons are discharged when the jumper is added.

g. When an AC source is connected in place of the battery, current flows in the circuit.



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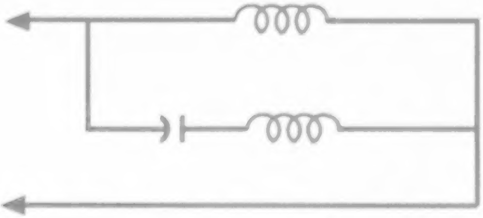
Information Sheet

h. Current does not flow across the gap between the plates, but back and forth, first toward one plate and then toward the other.

i. Capacitors not only allow alternating current flow, but cause the current in a capacitive circuit to lead or stay ahead of the voltage.

j. Placing a capacitor in series with an inductive load therefore tends to cancel out the lagging effect of the inductive load on the current and current and voltage will be nearly in phase.

k. Two coils or windings placed in a motor, one with and one without a capacitor, will be out of phase with each other and create the torque necessary to start the motor.



l. A capacitor may be called a capacitor or a condenser and may be indicated by the symbol -)| or -||-.

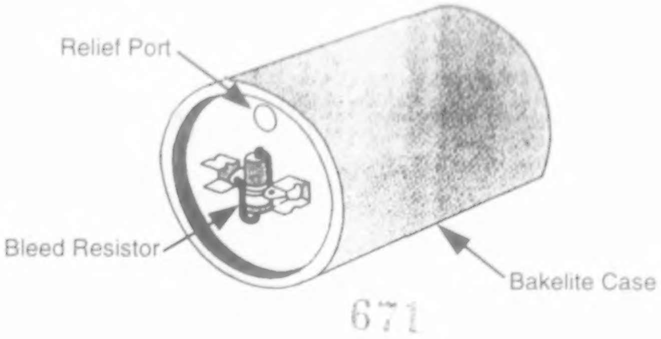
Note: The symbol -||- is most often associated with the term condenser as used in electronics.

5. **Types of capacitors**

a. There are two types of capacitors, start capacitors and run capacitors.

b. Start capacitors are used only while a motor is starting.

c. Start capacitors are round with a plastic-like bakelite case.



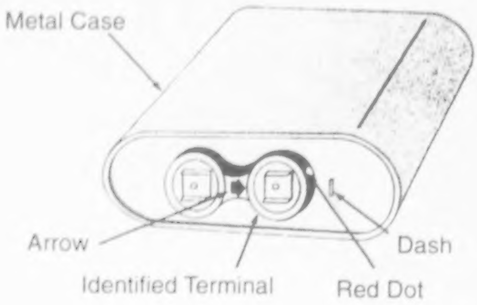
Information Sheet

d. Start capacitors usually have a bleed resistor connected across the capacitor terminals which discharges the capacitor after it is disconnected from power.

e. Most start capacitors have a relief port which permits safe release of pressure in the event of capacitor failure.

f. Run capacitors are used continuously while a motor is running.

g. Run capacitors may be either oval or round with a metal case.



h. Run capacitors are filled with oil or some other substance to dissipate the heat generated by continuous operation.

i. A run capacitor may have an identifed terminal which is connected to the capacitor plate nearest the metal case.

j. The identified terminal is usually indicated by an arrow, a red dot, or a dash.

CAUTION: If a capacitor that shorts out has been wired improperly, the capacitor and the motor will be damaged; but if the capacitor is wired properly, only the capacitor will be damaged if it shorts out.

k. Some run capacitors are internally fused to help prevent motor winding damage due to a shorted capacitor.

l. In some applications, two run capacitors are built into one case and called a dual-run capacitor.

6. **Guidelines for capacitor replacement**

a. Capacitors have a voltage rating which is the maximum voltage that may be safely applied to the capacitor.

b. Never install a capacitor with a voltage rating lower than the one being replaced.

Information Sheet

c. Capacitors have a microfarad rating, mfd or µF, which is the amount of capacitance of a capacitor.

Note: Microfarad is often abbreviated mfd or presented in scientific notation as µF, and although some OEMs use UF or variations such as uf, the notations all stand for microfarad.

d. Replacement run capacitors should have an mfd rating ±10% of the original.

e. Replacement start capacitors should have the same mfd rating or no more than 10% to 20% higher than the original.

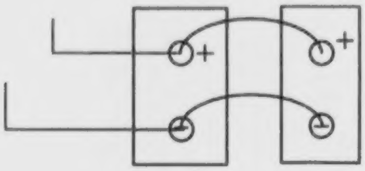
7. Grouping capacitors

a. When a technician does not have the proper replacement capacitor, capacitors can be grouped or connected together to produce a proper voltage or mfd rating.

b. Capacitor manufacturers do not recommend grouping more than two capacitors.

c. The mfd rating of capacitors connected in parallel is equal to the sum of the mfd rating of the individual capacitors.

Example: Two 20 mfd rated capacitors connected in parallel would have a combined rating of 40 mfd.



d. The voltage rating of each capacitor connected in parallel must be equal to or greater than the voltage rating of the capacitor being replaced.

e. The mfd rating of capacitors connected in series can be calculated using the following formula:

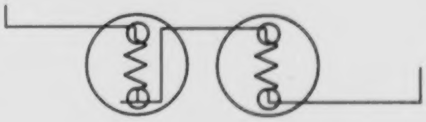
$$C_T = \frac{C1 \times C2}{C1 + C2}$$

Example: The mfd rating of two 20 mfd capacitors would be calculated as follows:

$$C_T = \frac{20 \times 20}{20 + 20} = \frac{400}{40} = 10 \text{ mfd}$$

Information Sheet

Note: Notice that two capacitors with the same rating combine in series to form a capacitor equal to one half the size of each.



f. The sum of the voltage ratings of capacitors connected in series must be equal to or greater than the voltage rating of the capacitor being replaced.

g. Each of the capacitors connected in series should have the same mfd rating.

Capacitors
Unit 11

Assignment Sheet 1—Calculate Ratings of Grouped Capacitors

Name____Overall rating_______

Evaluation Criteria	**Rating**
Number of calculations attempted	_____
Number of correct calculations	_____

Directions: Refer to appropriate information in Objective 7 and apply the appropriate formula to calculate the ratings for the following groups of capacitors.

A. Capacitors connected in series:

(1) 5 mfd, 110 VAC, and 5 mfd, 110 VAC.

Answers__________mfd___________VAC.

(2) 160 mfd, 250 VAC, and 160 mfd, 350 VAC.

Answers__________mfd__________VAC.

(3) 140 mfd, 270 VAC, and 140 mfd, 270 VAC.

Answers___________mfd__________VAC.

(4) 10 mfd, 250 VAC, and 10 mfd, 110 VAC.

Answers____________mfd__________VAC.

(5) 35 mfd, 250 VAC, and 35 mfd, 440 VAC.

Answers__________mfd____________VAC.

B. Capacitors connected in parallel.

(1) 5 mfd, 110 VAC, and 10 mfd, 110 VAC.

Answers__________mfd__________VAC.

Assignment Sheet 1

(2) 20 mfd, 250 VAC, and 160 mfd, 330 VAC.

Answers__________mfd__________VAC.

(3) 140 mfd, 440 VAC, and 140 mfd, 330 VAC.

Answers__________mfd__________VAC.

(4) 10 mfd, 250 VAC, and 10 mfd, 120 VAC.

Answers__________mfd__________VAC.

(5) 35 mfd, 250 VAC, and 160 mfd, 250 VAC.

Answers__________mfd__________VAC.

Capacitors
Unit 11

Job Sheet 1—Check Capacitors With an Analog Ohmmeter

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Capacitor properly discharged	_____
Proper checks made for opens, shorts, and grounds	_____
Evaluation of inspection and checks recorded	_____

A. Tools and materials

Assorted sizes of run capacitors
Assorted sizes of start capacitors
Analog ohmmeter w/Rx10K scale or higher
Bleed resistor
Safety glasses

B. Procedure

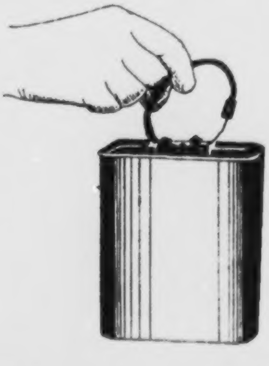
☐ 1. Put on safety glasses.

☐ 2. Select run and start capacitors as directed by your instructor, and use the following procedure to check each capacitor.

☐ 3. Observe start capacitors for signs of fluids leaking out and for a ruptured relief port; if you find either condition, the capacitor should not be used.

☐ 4. Observe run capacitors for signs of swelling or distortion of the metal case; if you find either condition, the capacitor should not be used.

☐ 5. Discharge the capacitor by placing a bleed resistor across the terminals.



CAUTION: Failure to discharge a capacitor can cause damage to an ohmmeter.

Note: Even though technicians in the field often use a screwdriver to discharge a capacitor, a bleed resistor should be used because some capacitors are internally fused and discharging them with a screwdriver would ruin them.

Job Sheet 1

☐ 6. If the capacitor has a permanent bleed resistor connected to the terminals, disconnect one side.

☐ 7. Set the ohmmeter to the Rx10K scale.

☐ 8. Touch ohmmeter leads to capacitor terminals and observe needle movement.

☐ 9. The capacitor is:

(a) shorted if the ohmmeter reads zero or shows a constant very low resistance.

(b) open if the ohmmeter reads infinity.

(c) leaky if the ohmmeter needle swings toward zero and then returns to a definite resistance and stays there, and

(d) producing capacitance if the ohmmeter needle swings toward zero and then slowly returns to infinity.

☐ 10. Reverse the leads at the capacitor terminals as many times as necessary to verify readings.

☐ 11. Check for grounding by touching one ohmmeter lead to a grounding terminal or to an unpainted spot on the metal case of run capacitors, and the other lead to each terminal.

☐ 12. Any reading except infinity indicates a grounded capacitor.

☐ 13. Record your evaluation of each capacitor you check.

#1 ____

#2 ____

#3 ____

☐ 14. Reconnect any disconnected bleed resistors.

☐ 15. Have your instructor check your evaluations.

☐ 16. Clean up area and return tools and materials to proper storage.

Comments: ____

____

____

Capacitors
Unit 11

Job Sheet 2—Check Capacitors With a Capacitor Analyzer

Name ________________________________ Attempt Number __________

Date ________________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Capacitor properly discharged	_____
Proper checks made for opens, shorts, and grounds	_____
Evaluation of inspection and checks recorded	_____

A. Tools and materials

Assorted sizes of run capacitors
Assorted sizes of start capacitors
Capacitor analyzer
Bleed resistor
Safety glasses

B. Procedure

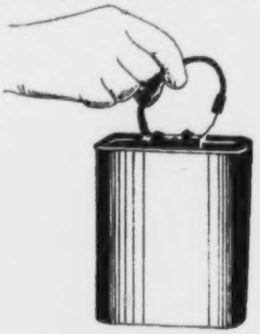
☐ 1. Put on safety glasses.

☐ 2. Select run and start capacitors as directed by your instructor, and use the following procedure to check each capacitor.

☐ 3. Observe start capacitors for signs of fluids leaking out and for a ruptured relief port; if you find either condition, the capacitor should not be used.

☐ 4. Observe run capacitors for signs of swelling or distortion of the metal case; if you find either condition, the capacitor should not be used.

☐ 5. Discharge the capacitor by placing a bleed resistor across the terminals.



CAUTION: Failure to discharge a capacitor can cause damage to an ohmmeter.

Note: Even though technicians in the field often use a screwdriver to discharge a capacitor, a bleed resistor should be used because some capacitors are internally and discharging them with a screwdriver would ruin them.

Job Sheet 2

☐ 6. If the capacitor has a permanent bleed resistor connected to the terminals, disconnect one side.

☐ 7. Read and follow the instructions for the analyzer you are using to check each capacitor for shorts, opens, leaking, grounds, and microfarad capacity.

☐ 8. Record your evaluation and the microfarad capacity of each capacitor you check.

#1 ______________________________ ____________ mfd

#2 ______________________________ ____________ mfd

#3 ______________________________ ____________ mfd

#4 ______________________________ ____________ mfd

☐ 9. Reconnect any disconnected bleed resistors.

☐ 10. Have your instructor check your evaluations.

☐ 11. Clean up area and return tools and materials to proper storage.

Comments:____

____

____

Capacitor Motors

Unit 12

Objective Sheet

Unit Objective

After completing this unit, the student should be able to draw connecting wiring for a CS motor with a current relay, a PSC motor, and a CSR motor. The student should also be able to wire a CS compressor motor with a current relay; wire a PSC motor; wire a CSR compressor motor; disassemble, inspect, clean, reassemble, and check operation of a PSC fan motor; use a hermetic analyzer to start, reverse, and check operation of a PSC compressor motor; and install a hard start kit. The student should demonstrate these competencies by completing the activities in the assignment and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to capacitor motors with their correct definitions.
2. Select true statements about how capacitors affect motors.
3. Complete statements about applications of capacitors to motors.
4. Select true statements about CS motor characteristics and applications.
5. Complete statements about PSC motor characteristics and applications.
6. Select true statements about CSR motor characteristics and applications.
7. Complete statements about troubleshooting capacitor motors.
8. Complete statements about troubleshooting capacitor motor start components.
9. Draw connecting wiring for a CS motor with a current relay. (Assignment Sheet 1)
10. Draw connecting wiring for a PSC motor. (Assignment Sheet 2)
11. Draw connecting wiring for a CSR motor. (Assignment Sheet 3)
12. Wire a CS compressor with a current relay. (Job Sheet 1)
13. Wire a PSC motor. (Job Sheet 2)
14. Wire a CSR compressor motor. (Job Sheet 3)

Objective Sheet

15. Disassemble, inspect, clean, reassemble, and check operation of a PSC fan motor. (Job Sheet 4)

16. Use a hermetic analyzer to start, reverse, and check operation of a PSC compressor motor. (Job Sheet 5)

17. Install a hard start kit. (Job Sheet 6)

Capacitor Motors
Unit 12

Information Sheet

1. **Terms and definitions**

   a. **Capacitor motors**–Motors which use a start capacitor and/or a run capacitor

   b. **Capacitor Start–Capacitor Run Motors (CSR)**—Motors which use both start and run capacitors

   c. **Capacitor Start–Induction Run Motors (CSIR or CS)**—Motors which use only start capacitors

   d. **Hard start kit**–A kit containing a potential relay and a start capacitor designed to be added to a PSC motor to convert it to a CSR motor

   e. **Permanent Split Capacitor Motors (PSC)**–Motors which use only run capacitors

2. **How capacitors affect motors**

   a. Although the primary reason for using capacitors with motors is to achieve starting torque, capacitors have other effects on motors.

   b. Using a capacitor too small can cause slow starting and excessive start amps.

   c. Since capacitance reduces running current, using a capacitor continuously can increase motor efficiency.

   d. Using a capacitor either too large or too small can cause a motor to overheat.

3. **Applications of capacitors to motors**

   a. All capacitor motors are essentially variations of the basic split-phase motor with a start winding and a run winding.

   b. All capacitors are connected in series with the start winding, so capacitor names run and start refer to "when" the capacitors are used and not "what" they are connected to.

   c. Start capacitors are used by motors only until the motor gets started, and run capacitors are used all the time motors are running.

   d. In split-phase motors, the start winding is disconnected as the motor gets up to speed.

e. In CS motors, the start winding is disconnected just like in a plain split-phase motor, but a start capacitor is added to the start winding circuit for added torque.

f. Some split-phase motors, small refrigeration compressor motors in particular, are designed to be convertible to CS motors by adding a start capacitor.

CAUTION: Adding a start capacitor to a split-phase motor not designed specifically to be converted to CS will cause permanent damage to the motor.

g. In PSC motors, the start winding is not disconnected, but remains connected through a run capacitor to reduce running amps during operation.

h. Using the run capacitor in a PSC motor starting circuit gives the motor more torque than a split-phase motor with no capacitor, but less torque than a CS motor with a start capacitor.

i. The CSR motor combines the features of a CS motor and a PSC motor by using a start capacitor connected temporarily to the start winding for initial torque, and a run capacitor connected continuously to the start winding during operation to reduce running amps.

Note: See Student Supplement 1 for comparison of different motor types.

4. **CS motor characteristics and applications**

a. CS motors are medium to large size, medium cost motors with medium to high torque and average running efficiency.

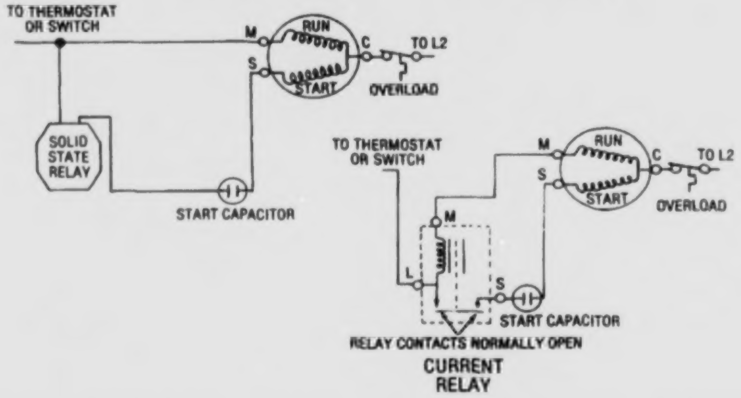
b. CS motors come in several single voltages or in dual voltage.

c. CS motors are usually single speed and rotation usually cannot be reversed.

d. Either an internal or external switch must be provided to remove the start capacitor and start winding from the circuit after a CS motor starts.

Information Sheet

Typical wiring for a CS hermetic compressor motor w/a current relay and w/a solid state relay


TO THERMOSTAT OR SWITCH
M
RUN
C
TO L2
S
START
OVERLOAD
SOLID STATE RELAY
START CAPACITOR
TO THERMOSTAT OR SWITCH
M
RUN
S
C
TO L2
START
OVERLOAD
M
L
S
START CAPACITOR
RELAY CONTACTS NORMALLY OPEN
CURRENT RELAY

Note: See Unit 6 for a description of current relays and their operation.

e. CS motors are used in such applications as:

   (1) belt drive blowers,

   (2) pumps,

   (3) refrigerator and freezer compressors,

   (4) small, commercial refrigeration, hermetic compressors, and

   (5) belt drive compressors.

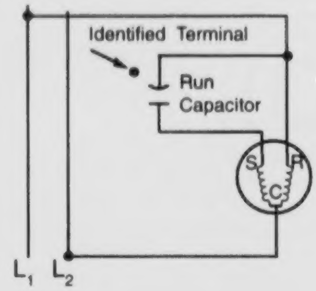
5. **PSC motor characteristics and applications**

   a. PSC motors are medium to large size, medium cost motors with medium torque and excellent running efficiency.

   b. PSC motors come in a wide range of single voltages, but not in dual voltage.

   c. PSC motors come in single or multiple speeds and direction of rotation can often be reversed.

   d. No internal or external switching must be provided on a PSC motor because the start winding is not disconnected.


Identified Terminal
Run Capacitor
S
R
C
L1
L2

Information Sheet

e. Some PSC motors are designed so that a potential relay and start capacitor may be added to convert a PSC motor to a CSR motor for increased starting torque.

f. A kit containing a potential relay, a start capacitor, and often brackets and wires needed to mount and connect the relay and capacitor is called a hard start kit.

CAUTION: The addition of a hard start kit to a PSC motor not designed to be converted to CSR will permanently damage the motor.

g. PSC motors are used in such applications as:

(1) medium size, direct drive fans and blowers,

(2) residential/light commercial air conditioning hermetic compressors,

(3) commercial refrigeration hermetic compressors,

(4) small, semi-hermetic compressors,

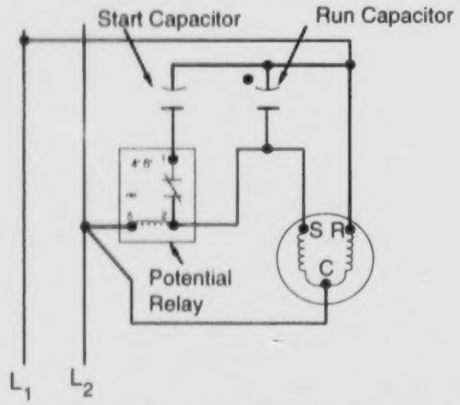
6. CSR motor characteristics and applications

a. CSR motors are medium to large size, high-cost motors with high torque and excellent running efficiency.

b. CSR motors come in several single voltages, but not in dual voltage.

c. CSR motors are usually single speed and rotation usually cannot be reversed.

d. CSR motors require the external switching of a potential relay to remove the start capacitor from the start winding circuit after a CSR motor starts, but like a PSC motor, the run capacitor is left in the circuit to improve running efficiency.



Note: See Unit 6 for a description of potential relays and their operation.

e. CSR motors are used primarily in compressors of all types, especially hermetic compressors.

Information Sheet

7. Troubleshooting capacitor motors

a. The mechanical components of open drive capacitor motors are serviced in the same way as all open-drive motors.

b. Open-drive CS motors use the same type of centrifugal controls as split-phase motors, and troubleshooting these controls is the same as for split-phase motors.

c. The key to troubleshooting most capacitor motor problems is determining if the problem is with the capacitors, other starting components, or the motor.

d. If a capacitor motor has voltage available but will not start or run properly, it will usually save time to check capacitors and start components before checking the motor.

e. The condition of capacitors and start components can also give good indications of what happened to failed motors.

Example: Burned out start capacitors usually indicate sticking start switches which often cause motor windings to burn out.

f. External motor starting components such as capacitors and start relays should usually be replaced anytime a capacitor motor is replaced.

Note: For additional troubleshooting assistance, see the Open Drive Electric Motor Troubleshooting Chart in Unit 8.

8. Troubleshooting capacitor motor start components

a. Because technicians often find that someone else has installed the wrong start component or wired the component improperly, always check for these problems before continuing any other troubleshooting.

b. Make sure the motor is operating under conditions for which it is rated, conditions such as ambient temperature, line voltage, duty cycle, and motor load.

c. Check such motor conditions as bearings, run amps, and back EMF.

d. Check starting switches or start relay contacts to make sure they are closed during starting and open when the motor is running.

e. Check start relays carefully for proper operation; if the coil is open or if there is any possibility the relay is not working properly, replace it.

f. Anytime a capacitor fails, check carefully for starting switches stuck closed or relays with contacts stuck closed because either condition always causes capacitor failure.

g. When a capacitor does not check open, shorted, or grounded, but the motor still has trouble starting, replace the capacitor or use an analyzer to check capacitor capacitance and compare it to capacitor rating.

Capacitor Motors
Unit 12

Student Supplement 1—Motor Characteristics Chart

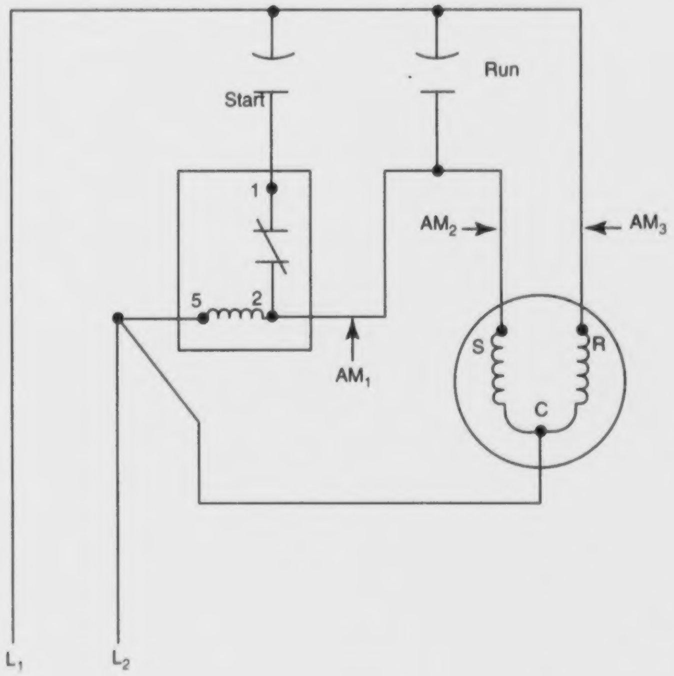
Motor Type	Starting Torque	Running Efficiency	Cost	Applications
Shaded Pole	Low	Fair	Low	Small fans, blowers, and timers
Split-Phase	Low to medium	Good	Low to moderate	Small to medium fans and blowers, and small hermetic compressors
CS	High	Good	Moderate	Medium to large fans and blowers, and small hermetic compressors
PSC	Medium	Excellent	Moderate	Medium fans, blowers, and compressors
CSR	High	Excellent	High	Medium to large compressors

Capacitor Motors
Unit 12

Student Supplement 2—Troubleshooting CSR Motors With an Ammeter

Directions: AM_1, AM_2, and AM_3 locations on the following schematic indicate points where an ammeter should be clamped around a wire to troubleshoot a CSR motor when proper voltage is available. The troubleshooting guide is on a separate page so you can place it alongside the schematic for easy reference.

CSR Motor Schematic



Student Supplement 2
CSR Motor Troubleshooting Guide

Meter Location	Normal Reading	Abnormal Reading	Possible Causes
AM_1	High current until motor starts and then zero or near zero	1. No current; motor may or may not start	a. Open start capacitor b. Open start relay contact c. Open start winding
		2. High current; motor hums until overload opens	a. Either capacitor shorted b. Start relay contacts shorted c. Start relay coil open d. Start winding shorted
AM_2	High current until motor starts and then low current	1. No current	a. Open start winding b. Open run capacitor and open start capacitor or contacts
		2. High current until motor starts and then zero	a. Open run capacitor
		3. High current; motor hums until overload opens	a. Shorted run capacitor b. Shorted start winding c. Open run winding
AM_3	High current until motor starts and then normal run amps	1. No current	a. Open run winding
		2. High current until overload opens	a. Shorted run winding b. Problems in start winding circuit (check AM_1 and AM_2)

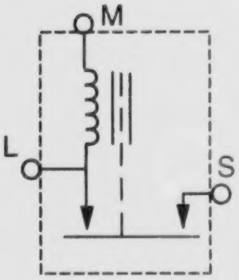
Capacitor Motors
Unit 12

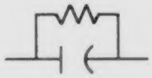
Assignment Sheet 1—Draw Connecting Wiring for a CS Motor With a Start Capacitor and a Current Relay

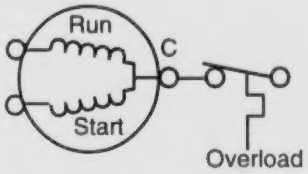
Name ______________________________ Overall Rating ______

Evaluation Criteria	**Rating**
Start capacitor connections properly drawn	______
Current relay connections properly drawn	______

Directions: Draw the connecting wiring for the CS motor, start capacitor, and current relay indicated in the following diagram.







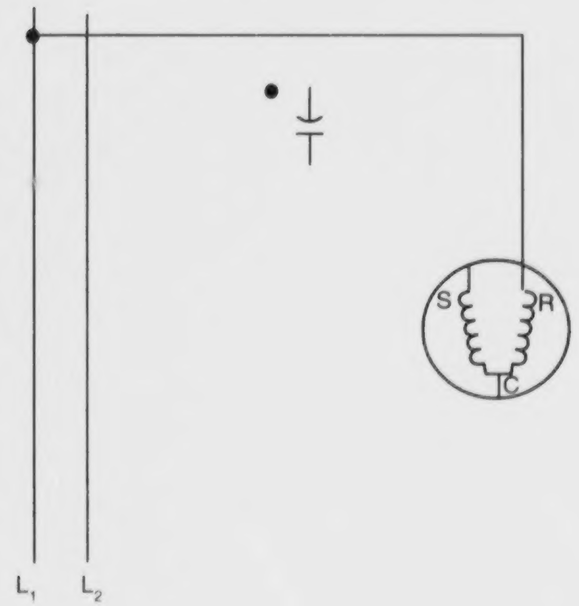
Capacitor Motors
Unit 12

Assignment Sheet 2—Draw Connecting Wiring for a PSC Motor

Name ______________________________ Overall Rating ______

Evaluation Criteria	Rating
Capacitor connections properly drawn	______
Motor connections properly drawn	______

Directions: Draw the connecting wiring for the PSC motor in the following diagram.



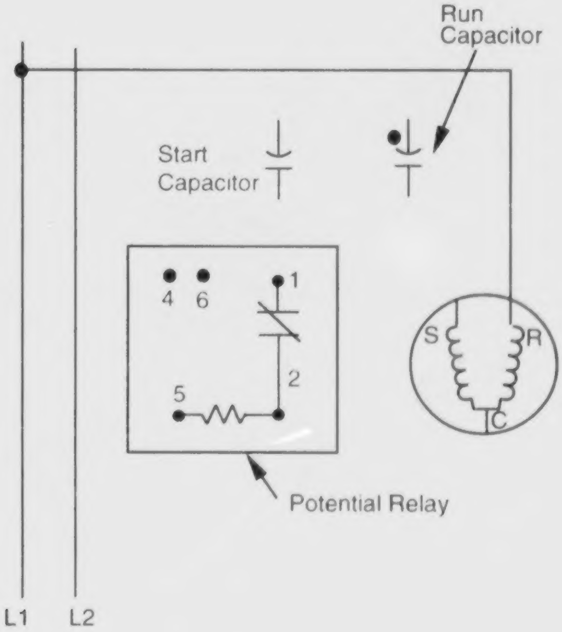
Capacitor Motors
Unit 12

Assignment Sheet 3—Draw Connecting Wiring for a CSR Motor

Name ____ Overall Rating ______

Evaluation Criteria	**Rating**
Start and run capacitor wiring properly drawn	______
Motor connections properly drawn	______

Directions: Draw the connecting wiring for the CSR motor in the following diagram.


Run Capacitor
Start Capacitor
4
6
1
2
5
S
R
C
Potential Relay
L1
L2

Capacitor Motors
Unit 12

Job Sheet 1—Wire a CS Compressor Motor With a Current Relay

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating __________

Evaluation Criteria	**Rating**
Data plate information recorded	_____
Windings verified and motor properly wired	_____
Electrical checks and evaluations properly completed	_____

A. Tools and materials

Refrigeration system or trainer w/a CS compressor,
current relay and start capacitor
ACR technician's hand tools
Ammeter
Voltmeter
Ohmmeter
Test cords or wiring as needed
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Check with your instructor for any special instructions.

☐ 3. Record the following information about the compressor motor:

Note: The required information may be on the unit data plate or on the compressor data plate.

(a) manufacturer ______________________.

(b) model # ______________________.

(c) serial # ______________________.

(d) volts ______________________.

(e) Ph ______________________.

(f) Hz ______________________.

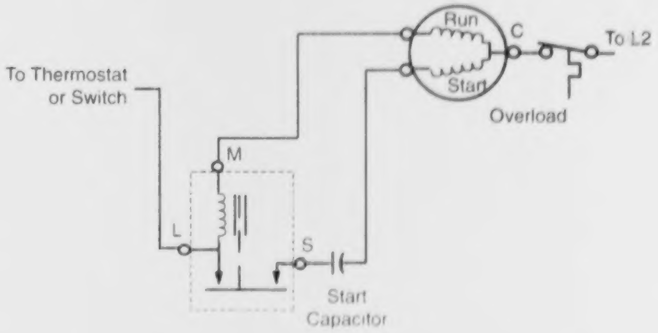
(g) FLA ______________________.

(h) LRA ______________________.

Job Sheet 1

☐ 4. Use an ohmmeter to determine which compressor terminals connect to which windings; sketch the terminal identification in the space that follows.

☐ 5. Wire motor and components according to the following diagram:



☐ 6. Connect test cord or wiring to appropriate voltage.

☐ 7. Place ammeter around one of the wires going to the start capacitor, and start the motor.

☐ 8. If the ammeter reads momentary amp draw and then drops to zero, the relay is operating properly; if the amperage draw does not drop to zero after about 10 seconds, turn off the power, and check the relay.

☐ 9. Record if relay is operating properly; yes ☐ , no ☐ .

☐ 10. Stop the motor.

☐ 11. Place an ammeter around the wire going to the common terminal, and start the motor.

☐ 12. Record start and run amps: start amps _______, run amps _______.

☐ 13. Compare readings to nameplate readings; acceptable ☐, unacceptable ☐.

Job Sheet 1

☐ 14 Place your hand on the motor shell; evaluate the temperature as: cool ☐, warm ☐ hot ☐.

☐ 15. Describe the motor vibrations: strong ☐, weak ☐, none ☐.

☐ 16. Listen to the motor and describe any unusual noises.

____

____

☐ 17. Have your instructor check your findings.

☐ 18. Clean up area and return tools and materials to proper storage.

Comments: ____________________________________

____

____

Capacitor Motors
Unit 12

Job Sheet 2—Wire a PSC Motor

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating __________

Evaluation Criteria	Rating
Motor information recorded for reference	_____
Terminals identified with ohmmeter	_____
Motor wired to specifications	_____

A. Tools and materials

Refrigeration system or trainer w/a PSC fan motor or PSC compressor motor
ACR technician's hand tools
Ammeter
Voltmeter
Ohmmeter
Test cords or wiring as needed
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Check with your instructor for any special instructions.

☐ 3. Record the following information about the motor:

Note: The required information may be on the unit data plate or on the motor data plate.

(a) manufacturer ____________________.

(b) model number ____________________.

(c) serial nummber ____________________.

(d) type code ____________________.

(e) Hp__ ____________________.

(f) volts ____________________.

(g) Ph ____________________.

(h) Hz ____________________.

(i) F.L.A. ____________________.

Job Sheet 2

(j) L.R.A. ______________________.

(k) RPM__________________________.

(l) Temp rise____________________.

(m) duty rating__________________.

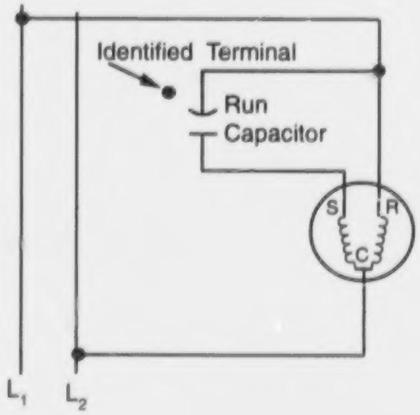
(n) S.F.__________________________.

(o) frame________________________.

(p) rotation__________: facing shaft end, yes ☐ , no ☐.

☐ 4. Use ohmmeter to determine which motor terminals connect to which windings, and sketch the terminal identification in the space that follows.

☐ 5. Wire motor and components according to the following diagram:


Identified Terminal
Run Capacitor
S
R
C
L₁
L₂

Job Sheet 2

☐ 6. Connect test cord or wiring to appropriate voltage.

☐ 7. Place ammeter around wire going to the common terminal, and start the motor.

☐ 8. Record start and run amps:

start amps______, run amps______.

☐ 9. Compare readings to nameplate readings; acceptable ☐, unacceptable ☐.

☐ 10. Place your hand on the motor shell and describe its temperature:

cool ☐, warm ☐, hot ☐.

☐ 11. Describe the motor vibrations:

strong ☐, weak ☐, none ☐.

☐ 12. Listen to the motor and describe any unusual noises.

____

____

☐ 13. Have your instructor check your findings.

☐ 14. Stop the motor and disconnect from power.

☐ 15. Clean up area and return tools and materials to proper storage.

Comments: ____

____

____

Capacitor Motors
Unit 12

Job Sheet 3—Wire a CSR Compressor Motor

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating __________

Evaluation Criteria	Rating
Motor information recorded for reference	_____
Start and run amps checked and compared	_____
Motor wired to specifications	_____

A. Tools and materials

Refrigeration system or trainer w/a CSR compressor motor
ACR technician's hand tools
Ammeter
Voltmeter
Ohmmeter
Test cords or wiring as needed
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Check with your instructor for any special instructions.

☐ 3. Record the following information about the compressor motor:

Note: The required information may be on the unit data plate or on the compressor data plate.

(a) manufacturer ____________________.

(b) model # ____________________.

(c) serial # ____________________.

(d) volts ____________________.

(e) Ph ____________________.

(f) Hz ____________________.

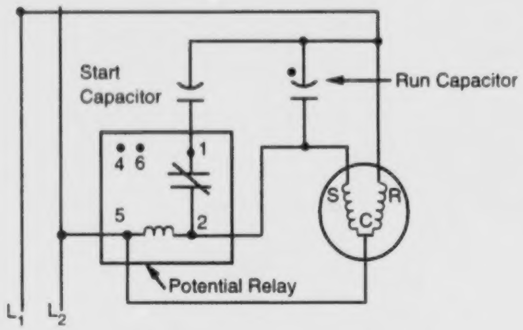
(g) FLA ____________________.

(h) LRA ____________________.

Job Sheet 3

☐ 4. Use ohmmeter to determine which compressor terminals connect to which windings, and sketch the terminal identification in the space that follows.

☐ 5. Wire motor and components according to the following diagram:



☐ 6. Connect test cord or wiring to appropriate voltage.

☐ 7. Place ammeter around one of the wires going to the start capacitor, and start the motor.

☐ 8. If the ammeter reads momentary amp draw and then drops to zero, the relay is operating properly; if the amperage draw does not drop to zero after about 10 seconds, turn off the power, and check the relay.

☐ 9. Record if relay is operating properly; yes ☐, no ☐.

☐ 10. Stop the motor.

☐ 11. Place ammeter around wire going to the common terminal, and start the motor.

☐ 12. Record start and run amps:

start amps __________, run amps ____________.

Job Sheet 3

☐ 13. Compare readings to nameplate readings:

acceptable ☐, unacceptable ☐.

☐ 14 Place your hand on the motor shell and describe its temperature:

cool ☐, warm ☐, hot ☐.

☐ 15. Describe the motor vibrations:

strong ☐, weak ☐, none ☐.

☐ 16. Listen to the motor and describe any unusual noises.

____

____

☐ 17. Have your instructor check your findings.

☐ 18. Stop the motor and disconnect from power.

☐ 19. Clean up area and return tools and materials to proper storage.

Comments: ____

____

____

Capacitor Motors
Unit 12

Job Sheet 4—Disassemble, Inspect, Clean, Reassemble, and Check Operation of a PSC Fan Motor

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating __________

Evaluation Criteria	Rating
Motor information recorded for reference	_____
Motor disassembled, inspected, cleaned, and reassembled	_____
Start and run amps and other electrical parameters checked	_____

A. Tools and materials

Assorted motors of different types
ACR technician's hand tools
Motor test cord
Ammeter
Ohmmeter
Bench vise
Compressed air
Motor cleaning fluid
Shop rags
Sand cloth
Extra fine sandpaper
Center punch or scratch awl
Soft-faced or rawhide hammer
Small socket set
Electric motor bearing oil
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Select PSC motor from motor assortment.

☐ 3. Record the following information from the motor data plate:

a. manufacturer____________________.

b. model number____________________.

c. serial number____________________.

d. type code____________________.

e. Hp____________________.

f. volts____________________.

Job Sheet 4

g. Ph________________________________.

h. Hz________________________________.

i. F.L.A.____________________________.

j. L.R.A.____________________________.

k. RPM_______________________________.

l. temp rise__________________________.

m. duty rating________________________.

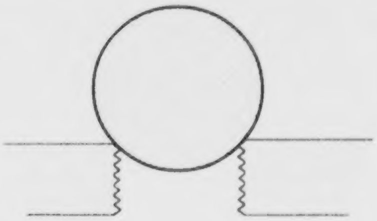
n. S.F._______________________________.

o. frame_____________________________.

p. rotation______________facing shaft end, yes ☐, no ☐.

☐ 4. Open the bench vise almost wide enough for the motor to fit between the jaws.

☐ 5. Place the motor across the opening in the jaws.



☐ 6. Clean the motor with compressed air.

CAUTION: Always use compressed air with extreme care because it can turn objects into missiles that fly through the air at great speed and pose a danger to people and property.

☐ 7. Clean off outer surface of motor with rags and cleaning fluid as needed.

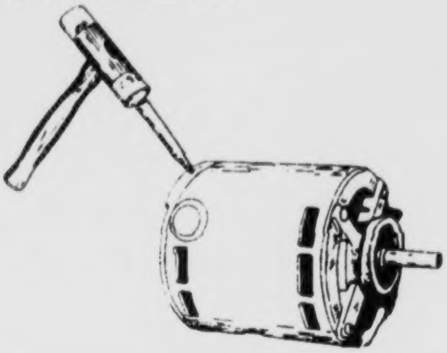
☐ 8. Clean the shafts or shafts with cleaning fluid and sand cloth as necessary.

☐ 9. Take hold of motor shaft and check side play: acceptable ☐, unacceptable ☐; check end play: acceptable ☐, unacceptable ☐.

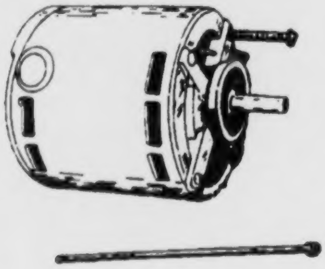
☐ 10. Have your instructor verify your findings.

Job Sheet 4

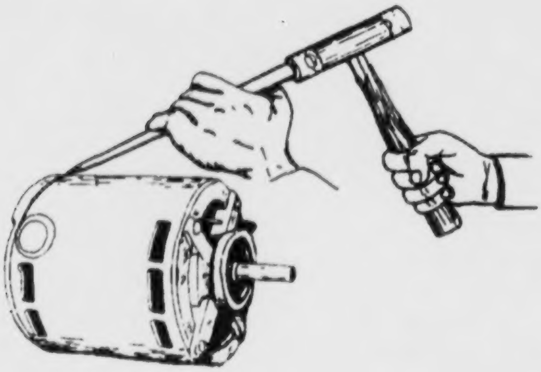
☐11. Use a center punch or a scratch awl to mark the end bells and the motor body with marks that can be used to realign the end bells and the body when the motor is reassembled.



☐12. Remove the bolts holding the end bells to the housing.



☐13. Use a soft-faced hammer and punch or awl to tap the end bells loose.



Job Sheet 4

☐ 14. Remove end bells.

☐ 15. Remove rotor.

☐ 16. Clean motor parts with compressed air.

☐ 17. Check to see if bearing wicks are full of oil by pushing on the wicks with your finger or a small screwdriver.

☐ 18. If no oil appears when wicks are pressed, soak wicks in oil.

Note: Use SAE 20 nondetergent oil if motor specifications are unknown.

☐ 19. Clean bearings.

CAUTION: Do not clean ball bearings with compressed air.

☐ 20. Check stator and rotor and shaft for signs of wear and misalignment.

Note: If new bearings are needed and there are no other signs of problems, the new bearings would be installed at this time.

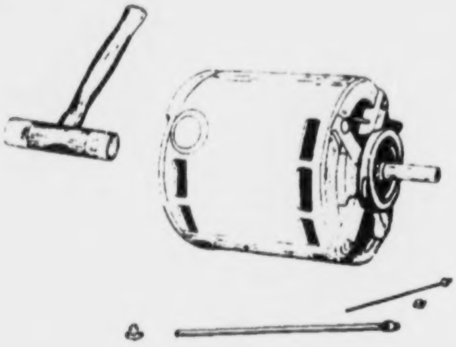
☐ 21. Oil shaft or shafts lightly.

☐ 22. Replace one end bell; if the motor is single-shafted, replace the end opposite the shaft first.

☐ 23. Insert rotor and replace other end bell loosely, making sure that all washers, spacers, or shims are in their proper place.

☐ 24. Align marks on end bells with marks on body.

☐ 25. Use a soft-faced hammer to tap end bells into place.



Job Sheet 4

☐ 26. Insert assembly bolts and tighten single bolts on opposite sides snugly at first and then tighten the other bolts, and then tighten the first two.

☐ 27. Turn the motor shaft by hand and check side play and end play.

☐ 28. If shaft is tight, loosen bolts and realign until the shaft turns properly.

☐ 29. Have your instructor inspect your assembly.

☐ 30. Use ohmmeter to check resistance of windings, and record readings:

#1__________ #2________ #3________.

☐ 31. Have your instructor inspect your findings.

☐ 32. Connect test cord to motor leads.

☐ 33. Clamp ammeter around one motor lead; if the motor is multi-speed, clamp around the common wire.

☐ 34. Connect test cord to power.

☐ 35. Record start amps __________ and run amps ________.

☐ 36. Compare amp readings to FLA:

acceptable ☐, unacceptable ☐.

☐ 37. Repeat amp check for each speed if it is a multi-speed motor.

☐ 38. Have your instructor check your findings.

☐ 39. Disconnect test cord.

☐ 40. Clean up area and return tools and materials to proper storage.

Comments: ____

____

____

Capacitor Motors
Unit 12

Job Sheet 5—Use a Hermetic Analyzer to Start, Reverse, and Check Operation of a PSC Compressor Motor

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
OEM instructions for analyzer read	_____
Windings checked for shorts, opens, and grounds	_____
Compressor started, reversed, and properly checked	_____

A. Tools and materials

Refrigerations system w/an operable PSC compressor
ACR Technician's hand tools
Hermetic analyzer
Ohmmeter
Rubber or rawhide mallet
Safety glasses

B. Procedure

☐ 1. Put on safety glasses

☐ 2. Read OEM instructions for the hermetic analyzer.

Note: Your instructor may demonstrate how to duplicate the functions of a hermetic analyzer with test cords, test instruments, and field wiring.

☐ 3. Check to be sure power is disconnected.

☐ 4. Remove wires from compressor terminals and note which wire was connected to which terminal.

☐ 5. Use ohmmeter to determine common, start, and run terminals if they are not marked or otherwise designated.

☐ 6. Connect hermetic anlyzer to compressor terminals as directed in instructions.

☐ 7. Have your instrtuctor check your connections.

☐ 8. Connect the analyzer to power supply of correct voltage for the compressor.

Note: Applying 240 VAC for a few seconds will sometimes start a mechanically siezed 120 VAC compressor.

Job Sheet 5

☐ 9. Use the analyzer to check compressor motor windings, and record your findings:

start winding: ________ ohms, open ☐, shorted ☐, grounded ☐;

run winding: ________ ohms, open ☐, shorted ☐, grounded ☐.

☐ 10. Have your instructor check your findings.

☐ 11. Use the analyzer to start the compressor.

☐ 12. If the compressor fails to start, bump the compressor with a rubber mallet and retry.

☐ 13. If the compressor still fails to start, use the analyzer to apply more capacitance (check with your instructor) and retry.

☐ 14. If the compressor still fails to start, use the analyzer to momentarily reverse the compressor.

☐ 15. Use the analyzer to run the compressor for a short length of time (check with your instructor) and record running amperage: ________________.

☐ 16. Disconnect the analyzer from the power supply and from the compressor.

☐ 17. Reconnect wires to compressor terminals.

☐ 18. Have your instructor check your connections.

☐ 19. Connect system to power and attempt to start.

☐ 20. If compressor will not start, a hard start kit will probably be needed.

☐ 21. Disconnect power.

☐ 22. Clean up area and return tools and materials to proper storage.

Comments: ____

____

____

Capacitor Motors
Unit 12

Job Sheet 6—Install a Hard Start Kit

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating __________

Evaluation Critera	**Rating**
Motor information properly recorded	_____
Hard start kit properly installed	_____
Start and run amps and motor operations evaluated	_____

A. Tools and materials

AC or refrigeration system w/a PSC compressor
ACR technician's hand tools
Hard start kit compatible w/system
Ammeter
Voltmeter
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Make sure power is disconnected from system.

☐ 3. Read OEM directions with the hard start kit and compare them with the wiring diagram on the system.

☐ 4. Record the following information about the compressor motor:

a. manufacturer__________________________.

b. model number____________________.

c. serial number__________.

d. type code___________________________.

e. Hp__________.

f. Volts_______________________.

g. Ph______________________.

h. Hz____________________.

i. F.L.A.__________.

j. L.R.A.__________.

Job Sheet 6

☐ 5. Make sure the hard start kit is the right size and type for the compressor.

☐ 6. Mount the start capacitor and potential relay according to the following guidelines:

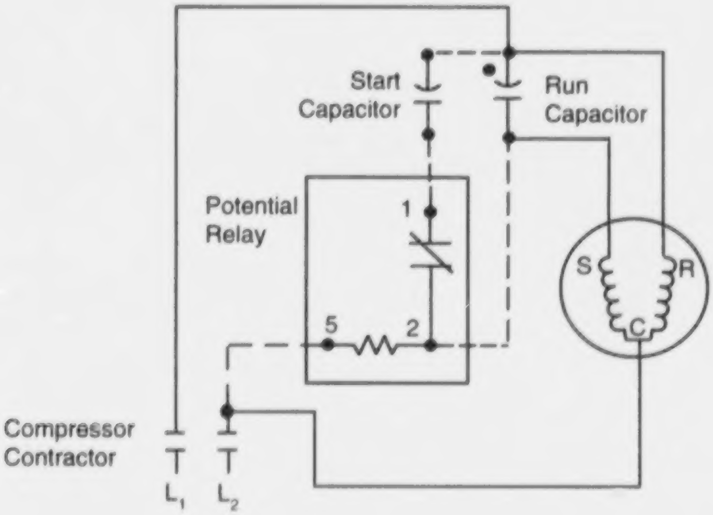
(a) locate components so that they will be protected from the weather.

(b) if start capacitor cannot be mounted inside the system electrical box, mount it upside down so that water will not accumulate around the terminals.

(c) locate components as close to the compressor run capacitor and compressor contactor as possible so required wiring will be as short as possible.

☐ 7. If the system diagram does not show how to wire hard start kit components, use the following diagram as a guideline.

Note: Many OEMs will include the wiring for hard start kit components as dotted lines and label them optional components.



☐ 8. Locate the compressor run capacitor and identify which side of it is connected to the compressor run terminal and which side is connected to the compressor start terminal.

☐ 9. Locate the compressor contactor and identify which contacts are connected to the compressor common terminal.

☐ 10. Connect wiring to components according to instructions and wiring diagrams.

Note: The easiest place to connect wiring is usually at the compressor run capacitor terminals and at the compressor contactor.

Job Sheet 6

☐ 11. Have your instructor check your installation.

☐ 12. Connect power to the system, start the system, and check operation of potential relay and compressor motor.

☐ 13. Record the following information:

a. compressor starts: yes ☐, no ☐.

b. potential relay contacts open: yes ☐, no ☐.

c. back EMF: ______________.

d. start amps __________; run amps ________.

☐ 14. Compare your findings with nameplate information and record your comparisons.

____

____

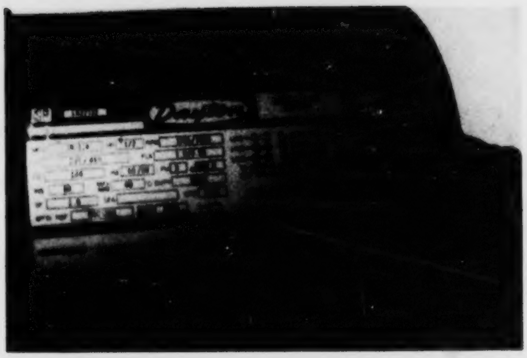
☐ 15. Have your instructor check your findings.

☐ 16. Clean up area and return tools and materials to proper storage.

Comments: ____

____

____



Three-Phase Motors

Unit 13

Objective Sheet

Unit Objective

After completing this unit, the student should be able to draw connecting wiring for wye wound and delta wound dual-voltage motors and wire a dual-voltage, three-phase motor, reverse rotation, and check operation. The student should demonstrate these competencies by completing the activities in the assignment and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to three-phase motors with their correct definitions.
2. Complete statements about characteristics and applications of three-phase motors.
3. Select true statements about three-phase motor construction.
4. Complete statements about wiring connections for three-phase motors.
5. Select true statements about troubleshooting three-phase motors.
6. Draw connecting wiring for wye wound and delta wound dual-voltage motors. (Assignment Sheet 1)
7. Wire a dual-voltage, three-phase motor, reverse rotation, and check operation. (Job Sheet 1)

Three-Phase Motors
Unit 13

Information Sheet

1. **Terms and definitions**

   a. **Delta**—Shaped like a triangle

   b. **Squirrel cage**—Shaped like the exercise wheel used by pet rodents

   c. **Synchronous speed**—The tendency of AC motors to adjust themselves to a constant speed depending on the AC frequency and the number of poles in the motor

   d. **Three-phase motor**—A motor that uses three-phase power which consists of three hot legs

   e. **Wye (Y)**—Shaped like the letter Y

2. **Characteristics and applications of three-phase motors**

   a. Three-phase motors are larger Hp and more expensive than single-phase motors, but achieve torque with smaller wire and fewer components.

   b. Three-phase motors come in several voltages and single or dual-voltage.

   c. Simpler construction and fewer components make three-phase motors more reliable than single-phase motors.

   d. Three-phase motors are used in such applications as:

      (1) large blowers and fans,

      (2) medium and large hermetic compressor motors,

      (3) semihermetic compressor motors,

   e. Single-phase and three-phase motors are sometimes used in the same piece of equipment such as a package heating/cooling unit with single-phase fan and blower motors and a three-phase compressor motor.

Information Sheet

3. Three-phase motor construction

a. Since three-phase motors use a three-phase power supply, they do not need to create the phase shift or split that single-phase motors require to achieve starting torque.

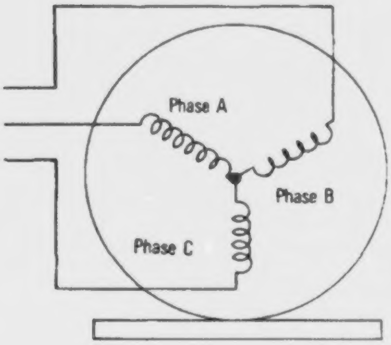
b. Three-phase motors have a stator with three windings of equal resistance.

c. Each winding is 120 electrical degrees out of phase with the adjacent winding which means that the attraction of the stator is continuously 120° ahead of the rotor.

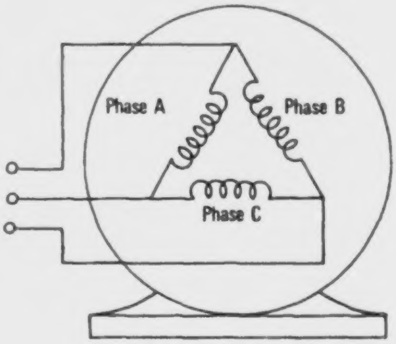
d. The continuous attraction/repulsion gives a three-phase motor both starting torque and continuous running torque.

e. Stator windings are either delta wound or wye wound.

Wye (also called Star) wound



Delta Wound



f. Three-phase motors must have either internal or external overload protection that disconnects at least two windings to prevent single-phasing which could cause the motor to burn up.

g. Three-phase motors are either syncronous or squirrel-cage.

h. Syncronous three-phase motors usually use an external DC source to excite the rotor for extra starting torque.

i. Squirrel-cage three-phase motors use a squirrel-cage rotor.

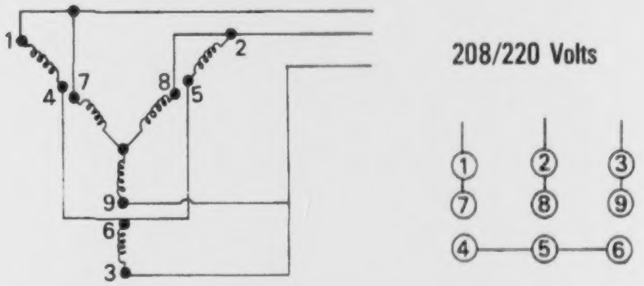
Information Sheet

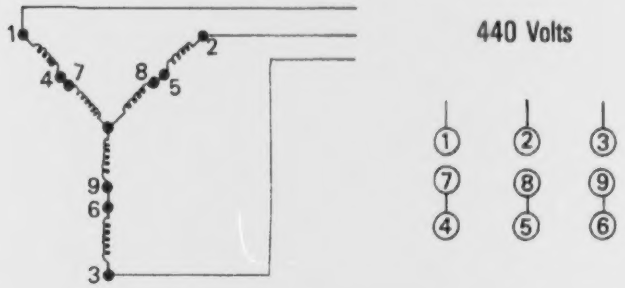
4. Wiring connections for three-phase motors

a. Single voltage three-phase motors have three leads which connect to the three legs of three-phase power.

b. Dual voltage three-phase motors may have six but usually have nine motor leads.

c. Typical connections for a three-phase motor which will operate on 208/220 VAC 3Ø power or 440 VAC 3Ø power are shown in the following diagrams.





d. The rotation of any three-phase motor may be reversed by switching any two of the line voltage leads.

5. Troubleshooting three-phase motors

a. Three-phase motors are subject to the same mechanical and cleanliness problems as any other motors.

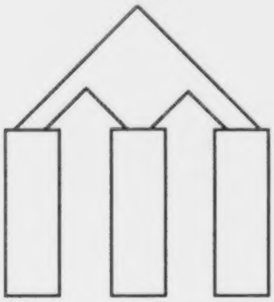
b. A common problem when troubleshooting three-phase motors is lack of proper three-phase power to the motor.

c. Lack of proper power can result from improper electrical service to the building or problems with building wiring.

d. It is critical that a technician check for proper power to the equipment disconnect and for proper power at the motor.

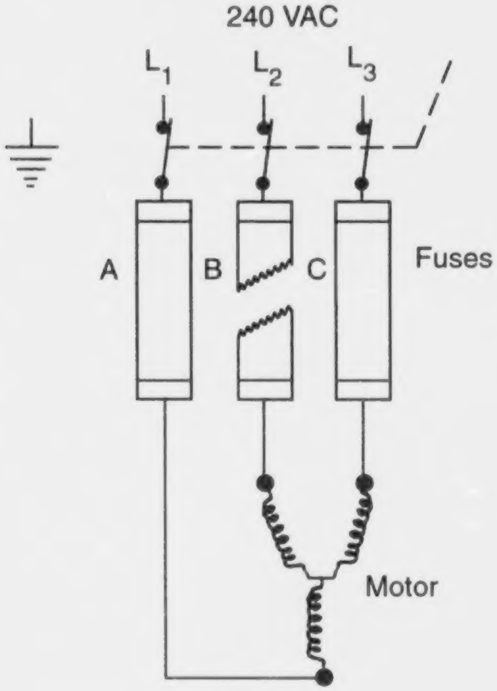
Information Sheet

e. To avoid misleading voltage readings, be sure to check incoming power all three ways, and with the disconnect open.



f. Rather than depending on voltmeter checks of fuses, remove fuses and check them with an ohmmeter.

Example: In the following illustration, a voltmeter would read 120V from the bottom of any of the three fuses to ground because the bottom of fuse B is still connected to fuses A and C through the motor.



Information Sheet

g. If the three-phase power supply has a wild leg, it is very important that the wild leg not be connected to any single-phase components in a system.

Note: See Unit 3 for a description of a wild leg.

h. An indication that two or more windings are open in a three-phase motor can be caused by an open internal overload, so allow plenty of time for the overload to reset before condemning the motor.

i. Any three-phase motor which does not have an open overload and is receiving proper voltage, should be removed for repair or replacement.

j. Open-drive three-phase motors can be repaired at a motor repair facility, but hermetic motors must be replaced.

Three-Phase Motors
Unit 13

Assignment Sheet 1—Draw Connecting Wiring for Wye Wound and Delta Wound Dual-Voltage Motors

Name ______________________________ Overall Rating ______

Evaluation Criteria	**Rating**
Number of drawings attempted	______
Number of drawings complete and correct	______

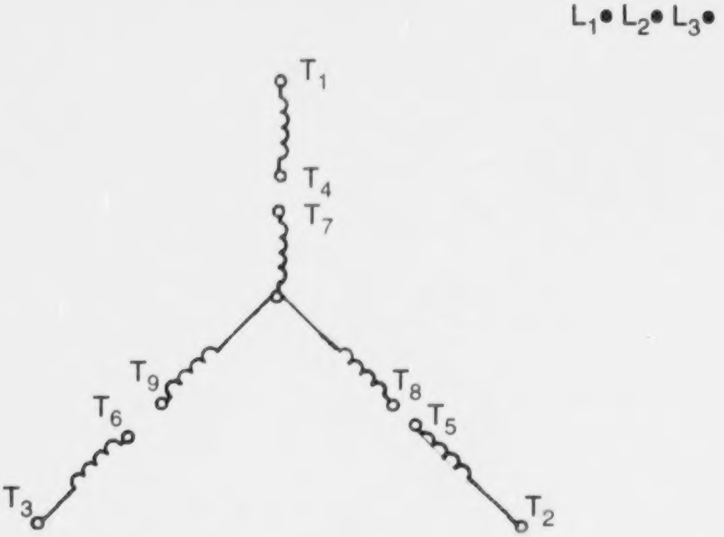
Directions: Draw connecting wiring for the wye wound and delta wound dual-voltage motors depicted in the drawings that follow. Refer to the information in the Motor Connections Chart to help you differentiate between high and low voltage connections.

Motor Connections Chart

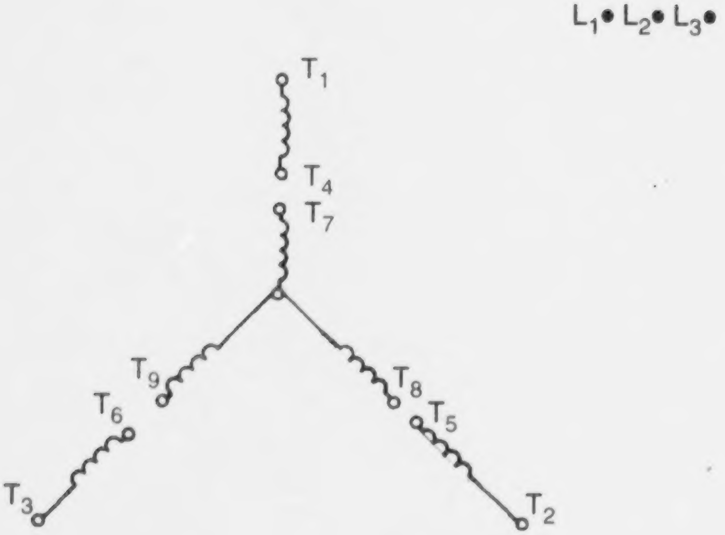
	Line	Wye (Star) Motor Lead	Line	Delta Motor Lead
Low Voltage	L^1	T^1 and T^7	L^1	T^1, T^2, and T^7
	L^2	T^2 and T^8	L^2	T^2, T^4, and T^8
	L^3	T^3 and T^9	L^3	T^3, T^5, and T^9
		T^4, T^5, and T^6 together		
High Voltage	L^1	T^1	L^1	T^1
	L^2	T^2	L^2	T^2
	L^3	T^3	L^3	T^3
		Connect T^4 to T^7		Connect T^4 to T^7
		Connect T^5 to T^8		Connect T^5 to T^8
		Connect T^6 to T^9		Connect T^6 to T^9

Assignment Sheet 1

Problem A: Wye (Star) wound—low voltage

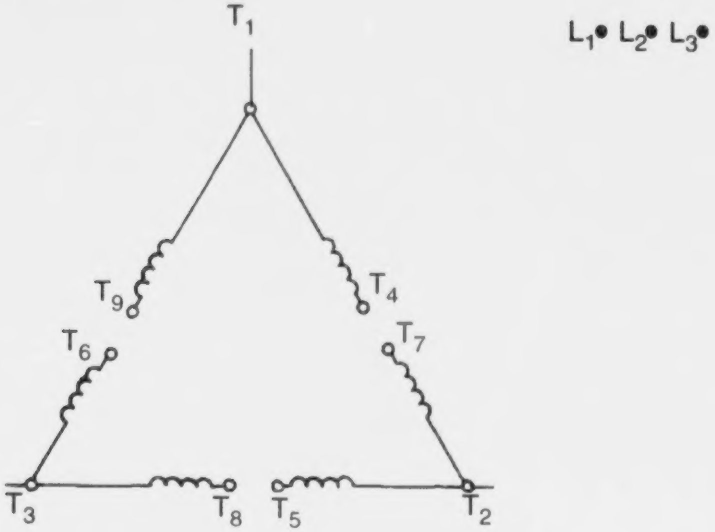

L1 L2 L3
T1
T4
T7
T9
T8
T6
T5
T3
T2

Problem B: Wye (Star) wound—high voltage

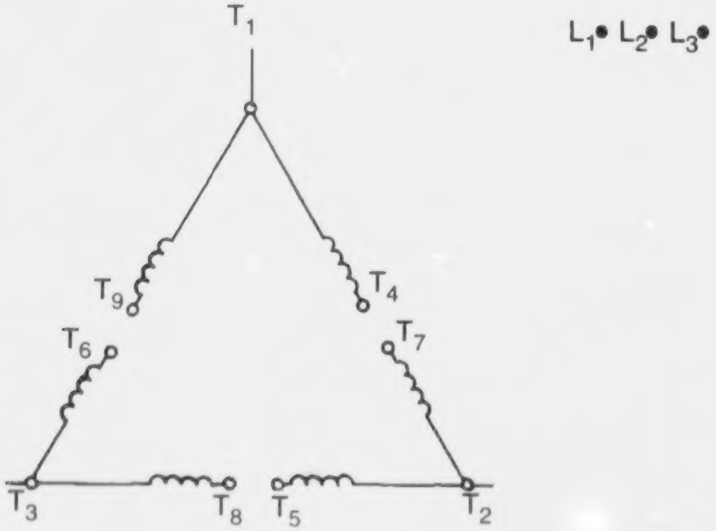

L1 L2 L3
T1
T4
T7
T9
T8
T6
T5
T3
T2

Assignment Sheet 1

Problem C: Delta wound—low voltage


T_1
L_1• L_2• L_3•
T_9
T_4
T_6
T_7
T_3
T_8
T_5
T_2

Problem D: Delta wound—high voltage


T_1
L_1• L_2• L_3•
T_9
T_4
T_6
T_7
T_3
T_8
T_5
T_2

Three-Phase Motors
Unit 13

Job Sheet 1—Wire a Dual-Voltage, Three-Phase Motor, Reverse Rotation, and Check Operation

Name ____________________ Attempt Number ______

Date ____________________ Overall Rating _______

Evaluation Critera	**Rating**
Nameplate information recorded for reference	______
Start and run amps checked and compared w/specifications	______
Motor rotation identified and reversed	______

A. Tools and materials

Assorted motors including a dual-voltage, three-phase motor
Power supply for one of the dual-voltage motor voltages
ACR technician's hand tools
Motor test cord or equivalent wiring
Ammeter
Voltmeter
Ohmmeter
Safety glasses

B. Procedure

☐ 1. Put on safety glasses.

☐ 2. Check with your instructor for any special instructions.

☐ 3. Check voltage of available three-phase power supply and record: ___________.

☐ 4. Select a dual-voltage, three-phase motor that will run on the available power supply.

☐ 5. Stabilize the motor so it will not move when running.

☐ 6. Record the following information from the motor data plate:

a. manufacturer_________________________.

b. model number____________________.

c. serial number__________.

d. type code__________________________.

e. Hp___________.

f. Volts________________________.

Job Sheet 1

g. Ph_________________________.

h. Hz_____________________.

i. F.L.A.___________.

j. L.R.A.___________.

k. RPM_______.

l. Temp rise_____.

m. duty rating_____.

n. S.F._____.

o. frame_____.

p. rotation_________; facing shaft end, yes ☐, no ☐.

☐ 7. Identify motor leads by labels or use an ohmmeter if labels are missing.

☐ 8. Connect motor leads according to OEM directions or typical wiring diagrams to match voltage available.

Note: Refer to Assignment Sheet 1 for additional help.

☐ 9. Connect test cord or equivalent wiring to the power supply.

☐ 10. Have your instructor check your work.

☐ 11. Use ammeter and start and stop motor as necessary to check start and run amps on each leg of power:

leg 1: start amps______run amps_____.

leg 2: start amps_____ run amps_____.

leg 3: start amps_____ run amps_____.

☐ 12. If current draw on all three legs is not close to identical, switch all three leads and repeat the previous step.

☐ 13. Compare readings to nameplate readings:

acceptable ☐, unacceptable ☐.

☐ 14. Identify direction of rotation:

____

☐ 15. Switch two leads, run motor, and verify that direction of rotation changes:

yes ☐, no ☐.

Job Sheet 1

☐ 16. Have your instructor check your findings.

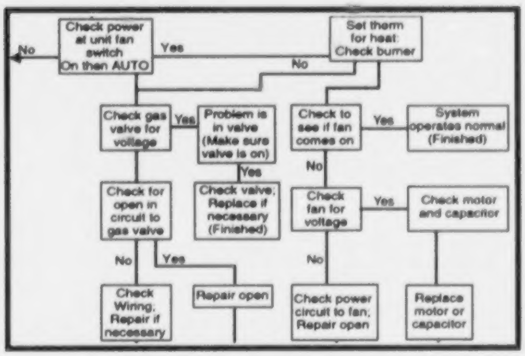
☐ 17. Disconnect motor from power and remove test cord.

☐ 18. Clean up area and return tools and materials to proper storage.

Comments:____

____

____


Check power at unit fan switch On then AUTO
No
Yes
Set therm for heat: Check burner
No
Check gas valve for voltage
Yes
Problem is in valve (Make sure valve is on)
Yes
Check valve; Replace if necessary (Finished)
Check to see if fan comes on
Yes
System operates normal (Finished)
No
Check for open in circuit to gas valve
No
Yes
Check fan for voltage
Yes
Check motor and capacitor
No
Check Wiring; Repair if necessary
Repair open
Check power circuit to fan; Repair open
Replace motor or capacitor

Troubleshooting ACR System Electrical Circuits

Unit 14

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify components and component operations from ACR electrical diagrams; select test meters or procedures for specific ACR system troubleshooting; and solve ACR electrical troubleshooting problems. The student should also be able to troubleshoot series, parallel, and series-parallel electrical circuits on selected ACR equipment. The student should demonstrate these competencies by completing the activities in the assignment and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to troubleshooting ACR system electrical circuits with their definitions.
2. Complete statements about guidelines for troubleshooting ACR system electrical circuits.
3. Select true statements about identifying circuit components and their operations.
4. Complete statements about guidelines for test meter selection.
5. Select true statements about using a voltmeter.
6. Solve problems about applying the hopscotch method for troubleshooting.
7. Select true statements about using an ammeter.
8. Complete statements about using an ohmmeter.
9. Complete statements about checking for shorts and grounds.
10. Select true statements about using jumpers.
11. Identify problems statements about troubleshooting techniques.
12. Identify components on ACR system electrical diagrams. (Assignment Sheet 1)

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Objective Sheet

13. Identify component operation from ACR system electrical diagrams. (Assignment Sheet 2)

14. Select test instruments or procedures for specific ACR system troubleshooting. (Assignment Sheet 3)

15. Solve ACR electrical troubleshooting problems. (Assignment Sheet 4)

16. Troubleshoot series electrical circuits on selected ACR equipment. (Job Sheet 1)

17. Troubleshoot parallel electrical circuits on selected ACR equipment. (Job Sheet 2)

18. Troubleshoot series-parallel electrical circuits on selected ACR equipment. (Job Sheet 3)

Troubleshooting ACR System Electrical Circuits
Unit 14

Information Sheet

1. **Terms and definitions**

   a. **Continuity**—A complete electrical path

   b. **Control**—Any device that operates or regulates electrical or mechanical systems

   c. **Ground**—An undesired path to the earth ground

   d. **Limit control**—A control which responds to such conditions as temperature or pressure and opens or closes circuits when maximum or minimum conditions are reached; usually used for safety purposes

   e. **Load**—Any device that uses or consumes electricity by converting it into heat, light, or mechanical motion

   f. **Open**—Lack of continuity in an electrical circuit

   g. **Operating control**—A control such as a thermostat which responds to a change in conditions and initiates action

   h. **Primary control**—A control such as a fan relay which responds to a signal from an operating control and stops and starts equipment such as motors or valves

   i. **Safety ground**—A direct path to an earth ground to prevent damage to equipment or injury to people

   j. **Short**—An improper path in an electrical circuit

2. **Guidelines for troubleshooting ACR system electrical circuits**

   a. Identify circuit components and their operation using electrical diagrams and information about the specific equipment.

   b. Select the appropriate test meter based on the status of the equipment and your own experience.

   c. Use test instruments and your senses and experience to establish where power is available, what is and what is not operating, how loads are operating, and where faults such as opens, shorts and grounds are located.

   d. Open switches, safety devices, or loads in series may have to be temporarily jumpered in order to identify the condition of the entire circuit or system.

Information Sheet

e. Recommend corrective action only after you have determined the relative cost or any additional problems.

Examples: (1) It may be worthwhile to replace a compressor in a newer unit, but not in an older one.

(2) It would be foolish to replace a contactor and then discover that the compressor does not work.

(3) Burnt contacts in a contactor could be caused by a compressor pulling too many amps because a condenser coil is dirty.

3. **Identifying circuit components and their operations**

a. In an operating ACR circuit, an operating control senses a need for a change in conditions and signals a primary control which starts or stops the equipment which will make the change, but only if the limit control senses that it is safe to do so.

Example: A heating thermostat, an operating control, senses that the room temperature is below the set point and signals the gas valve, a primary control, to open and supply gas to burn and provide heat, but only if the temperature limit control senses that it is not too hot in the furnace.

b. In order to troubleshoot ACR electrical systems, a technician must identify which components are loads, what is controlling each load, and what type of controls they are.

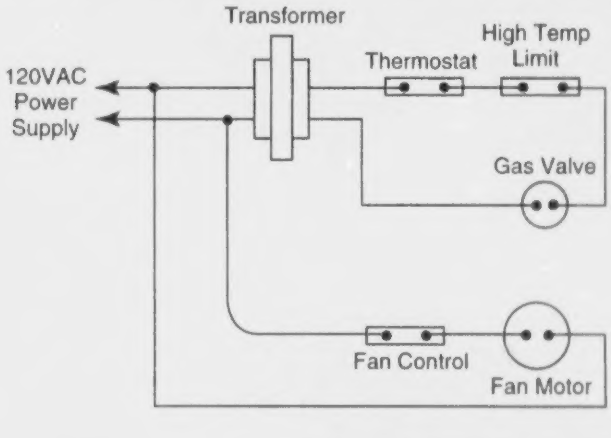
c. The power supply or source and amount of voltage must also be identified.

d. In the following pictorial the electrical components can be identified as:

(1) sources: 120VAC power supply and the 24VAC secondary of the transformer,

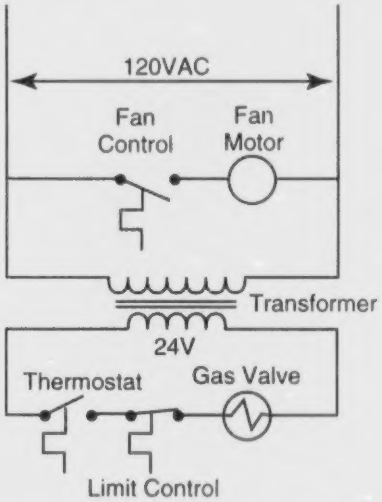
(2) loads: fan motor, gas valve, and primary of the transformer, and

(3) controls: fan motor controlled by fan control, gas valve controlled by thermostat and limit control, and the transformer primary has no control.



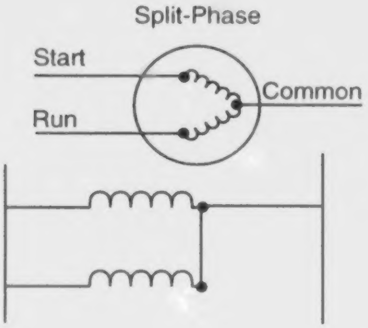
Information Sheet

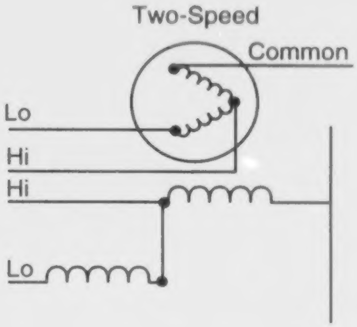
e. Converted to a ladder schematic using symbols which show component functions, the system in the pictorial looks like the following.


120VAC
Fan Control
Fan Motor
Transformer
24V
Thermostat
Gas Valve
Limit Control

f. A single device often contains more than one electrical component such as the transformer in the system above which is treated as a load in the primary and a source in the secondary.

g. Motors with more than one winding such as two-speed motors and split-phase motors are two loads in one device which the following diagrams illustrate.


Split-Phase
Start
Common
Run


Two-Speed
Common
Lo
Hi
Hi
Lo

4. **Guidelines for test meter selection**

a. Which test meter to use in a given situation depends on the status of the equipment and the technician's experience.

b. Use a voltmeter to determine if source voltage is available to the equipment or to a specific component.

c. When the system is fully or partially operating, use a voltmeter to determine at what point the circuit is broken.

Information Sheet

d. Use an ammeter to determine whether a load such as a motor or electric heat strip is operating properly, that is, drawing the correct amount of current.

e. An analog ammeter or a digital ammeter capable of reading momentary amp draw is essential in checking motor starting amps and starting components.

f. Use an ohmmeter to check for continuity of a circuit or component.

g. Use an ohmmeter only with:

   (1) the power turned off or disconnected,

   (2) capacitors discharged, and

   (3) the circuit or component isolated.

h. To use voltmeters and ammeters, power must be on, but to use an ohmmeter, power must be off.

5. **Using a voltmeter**

a. The first step in almost any troubleshooting situation is to determine if power is available to the equipment.

b. If any line voltage components are operating, it requires no meter to come to the conclusion that power is available.

c. If no components are operating, use a voltmeter to check for voltage at the point where the source of supply enters the equipment.

d. If voltage is present, the problem is in the equipment; if voltage is not present, the problem is in the source.

e. If the problem is in the source, use the voltmeter to check at points such as fuses or breakers to determine where power stops.

f. Blown fuses or breakers are indications that some load is probably drawing too much current.

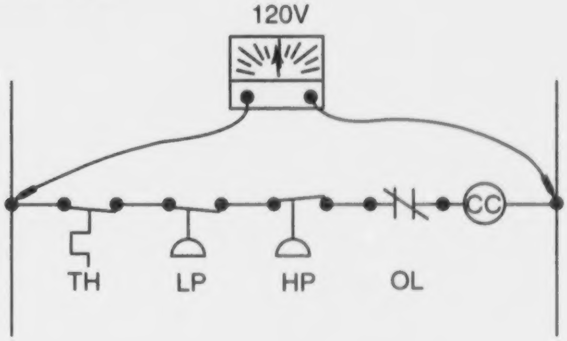
g. If voltage is available to the equipment, use a voltmeter to check if voltage is available to individual loads.

h. Once you have established that voltage is available to the equipment but not to the load, the simplest way to determine which component in a circuit is open is to use the hopscotch method.

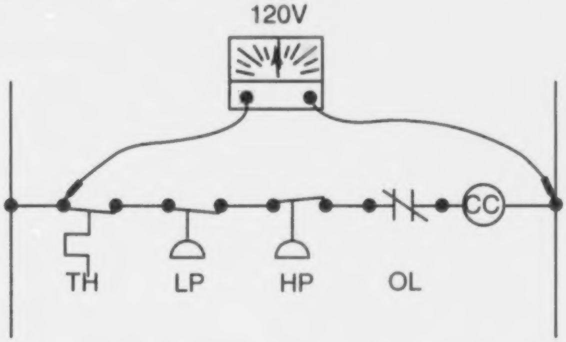
Information Sheet

6. Applying the hopscotch method for troubleshooting

a. After you have established that voltage is available to the equipment but not to the load, begin the hopscotch troubleshooting method by measuring voltage across the entire circuit.



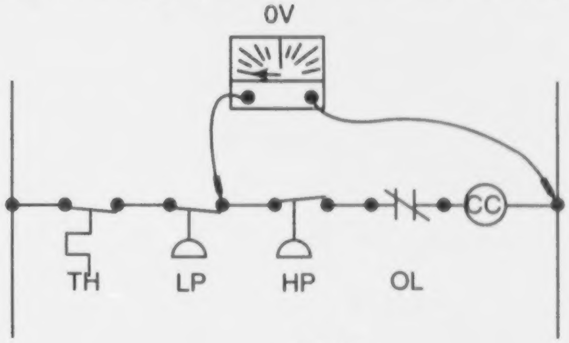
b. Next, move the left lead to the other side of the first switch, that is, hop over the switch.



c. If voltage is present, the first switch is closed and is not the problem; If voltage is not present, the first switch is open and you have identified the problem.

d. If the first switch is not the problem, use the left lead to hop over each switch in order until the open is identified.

Example: In the following graphic, the meter indicates an open low-pressure switch.



Information Sheet

e. Although an open is occasionally a broken wire or a loose connection, an open is usually caused by an open switch.

f. Once hopscotching helps you isolate an open, make every effort to determine why the open occurred and do your best to correct the problem before operating the equipment.

7. **Using an ammeter**

a. Use an ammeter to test the amount of current a load is drawing, and compare the amp draw to the OEM specifications.

b. Name plate rating for F.L.A. represents amp draw under full load conditions, so be sure to evaluate the operating conditions of the load.

Example: Since air conditioners are rated as under full load when operating on a 95°F day, an AC compressor motor running on an 80°F day would be expected to draw less than F.L.A.

c. Ammeter checks of a CSR motor tell a technician not only the condition of the motor, but also the condition of the starting components, and an analog ammeter can be used to evaluate the operation of many motors.

Note: See Student Supplement 1.

d. Use an ammeter to determine if loads you cannot see are or are not operating.

Example: An electric heating element is working if it draws any amps at all.

e. When the meter you are using does not have a scale small enough to read the very low current draw of some loads, wrap the wire several times around the ammeter jaws and divide the motor reading by the number of passes the wire makes through the jaws.

f. To prevent damage to an ammeter, remember that motors have relatively high starting amps, so be sure to set an ammeter high enough to handle three to four times F.L.A. and then change to a lower scale after the motor starts.

g. Because of the short duration of start amps, most digital ammeters will not read start amps.

8. **Using an ohmmeter**

a. Use an ohmmeter to check continuity or to find opens, shorts, and grounds.

b. Before using an ohmmeter, disconnect the power and at least one end of the component you are checking.

CAUTION: Using an ohmmeter with power present will cause serious damage to the meter.

Information Sheet

c. Use an ohmmeter for checking circuits only if the circuit has been isolated from other circuits and components.

d. To avoid misleading readings and misinterpreting ohmmeter readings, remove a component before checking it with an ohmmeter.

e. Zero an ohmmeter before using it and each time you change scales because it is the only way to assure accurate readings.

f. A reading of infinity indicates an open fuse, switch, or wire while a reading of zero ohms or very near zero ohms indicates continuity because the ohmmeter was able to send an electrical signal through the component.

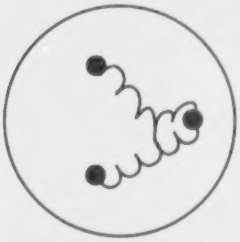
g. An open load will also have infinite resistance, but the proper resistance of a load can only be obtained from OEM specifications.

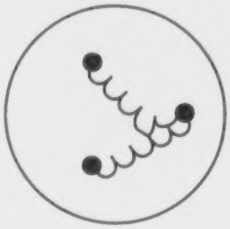
h. Do not use an ohmmeter to test most solid-state devices because solid-state devices can be damaged by the battery current of the meter.

9. Checking for shorts and grounds

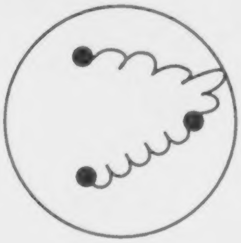
a. The symptoms for shorts and grounds are similar and technicians often confuse one with the other.

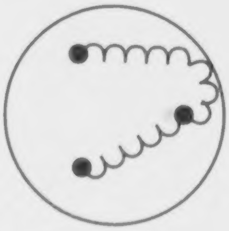
b. A short occurs when electricity takes an alternative path or shortcut such as when motor windings touch each other where they should not.





c. A ground occurs when electricity takes a direct path to ground such as through an equipment case.





Information Sheet

d. Either a shorted or a grounded load will usually blow a fuse or trip a breaker because the current is allowed to flow without being impeded by the designed load.

e. Resistance readings of a shorted load are lower than OEM specifications.

f. A shorted switch or shorted wiring will usually cause a load to continue to operate when it is not supposed to be operating.

Example: A cooling unit would continue to run after desired temperature is reached if contactor contacts are shorted.

g. The most important thing to do when checking for shorts with an ohmmeter is to isolate the circuit or the load being tested.

h. Check for a ground with an ohmmeter by placing one probe on the component and the other probe on a known ground such as the green wire on a grounded cord or copper tubing in a refrigeration system.

10. **Using Jumpers**

a. Since an open operating switch, open safety switch, or open wiring or connections will usually not allow a circuit or system to operate, the open may need to be temporarily jumpered to find out if the rest of the circuit or system will operate.

b. Be sure to look the system over for any obvious faults, such as burnt spots, loose wiring or stuck motors before jumpering any components.

c. Jumpering may be as simple as manually pushing in contacts or the applying of additional wires.

d. Jumpers may be simply pieces of wire or manufactured jumpers with alligator clips on each end.

e. Be sure power is off or disconnected before using jumpers.

Information Sheet

f. Be prepared to turn power off quickly when restoring power to test the circuit.

   Note: If a power switch is not close, enlist the help of a coworker or install a temporary switch in the line.

g. Restore power only long enough to determine what is or is not working in the circuit or system.

h. If the load does not operate, use the hopscotch method to find additional opens.

i. Additional jumpers can be used for any additional opens.

j. Be sure to remove all jumpers when checks are completed.

11. **Troubleshooting techniques**

a. The basic technique for most electrical troubleshooting is a process of elimination.

b. The process of elimination involves separating circuits and components that are operating properly from circuits and components that are not operating properly.

c. The process of elimination begins with a diagnosis of the problem which requires finding out two things:

   (1) what the equipment **should** be doing, and

   (2) what the equipment **is** doing.

d. To find what the equiment should be doing, a technician should look to the following:

   (1) equipment history as reflected in company or customer records,

   (2) the technician's own field experience or the experience of other technicians as found in troubleshooting charts and service literature, and

   (3) equipment wiring diagrams.

e. To find out what the equipment is doing, a technician should look to the following:

   (1) customer complaints,

   (2) system observation, and

   (3) technician test results.

Information Sheet

f. A comparison of what the equipment should be doing with what the equiment is doing should eliminate some parts of the system as the source of the problem.

Example: On a no cool call, if the fan is running in the indoor section of a split cooling system and the outdoor section is humming, the indoor section can be eliminated as containing the source of the problem because the fan running indicates the indoor section has both line voltage and control voltage, and the outdoor section humming indicates that the controls are probably sending a signal to the outside.

g. Once a technician has determined which electrical circuits or which sections of the equipment contain the probable sources of the problem, the technician must isolate the specific fault.

h. A technician isolates a specific fault by using a troubleshooting procedure found in such things as:

(1) the technician's experience with similar equipment,

(2) OEM installation, startup, and service instructions furnished with the equipment,

(3) troubleshooting charts or tables,

(4) fault isolation diagrams or troubleshooting trees, and

Note: See the troubleshooting tree in Student Supplement 2.

(5) OEM instructions for using and interpreting diagnostic tests built into the equipment.

Example: Many solid-state control boards contain testing features which permit the technician to apply a jumper to test points and get a readout of the problem or a light flashing a specific number of times to indicate a problem that is identified in literature.

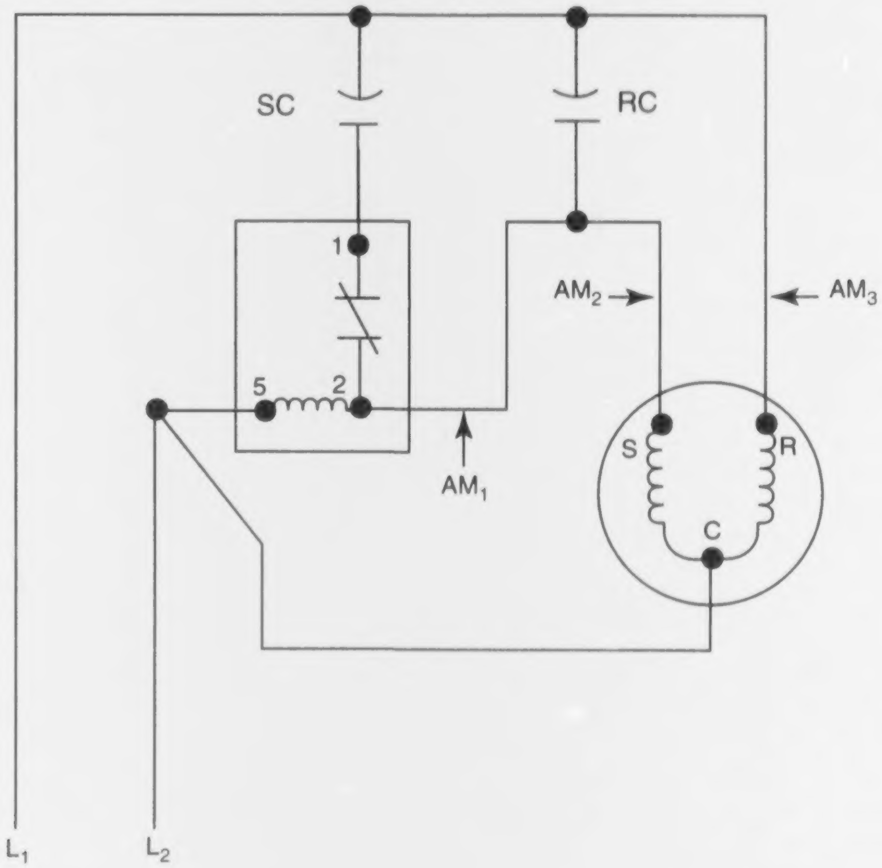
i. Once a fault is identified, use appropriate test instrument checks to determine the exact nature of the fault and what corrective action to take.

Example: A fault identified as a compressor problem may be in the compressor motor, connections to the compressor, or in starting components, if present.

Troubleshooting ACR Electrical Systems
Unit 14

Student Supplement 1—Troubleshooting CSR Motors With an Ammeter

Directions: AM_1, AM_2, and AM_3 locations on the following schematic indicate points where an ammeter should be clamped around a wire to troubleshoot a CSR motor when proper voltage is available. The troubleshooting guide is on a separate page so you can place it alongside the schematic for easy reference.



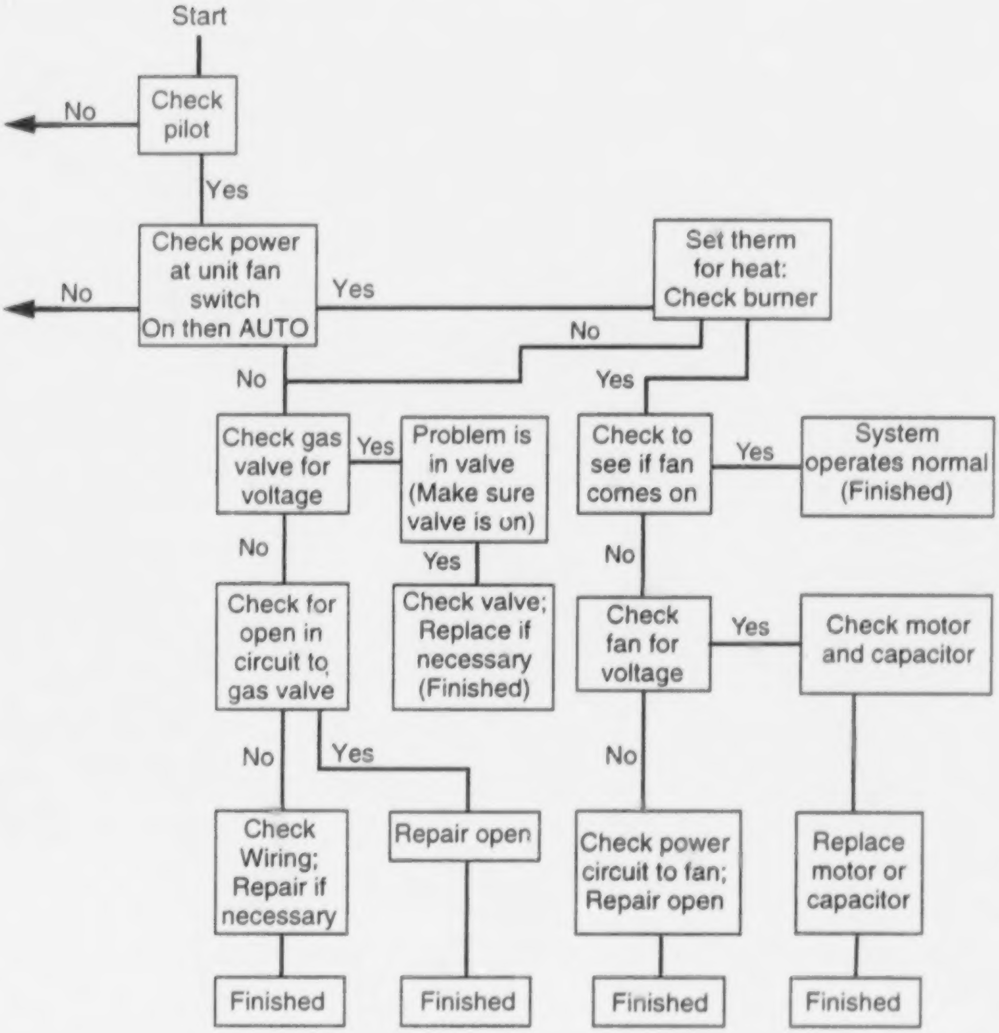
Student Supplement 1

Student Supplement 1—Troubleshooting CSR Motors With An Ammeter

Meter Location	Normal Reading	Abnormal Reading	Possible Causes
AM$_1$	High current until motor starts, usually very brief, and then zero	1. No current; motor may or may not start	a. Open start capacitor b. Open start relay contacts c. Open start winding
		2. High current; motor hums until overload opens	a. Either capacitor shorted b. Start relay contacts shorted c. Start relay coil open d. Start winding shorted
AM$_2$	High current until motor starts and then low current	1. No current	a. Open start winding b. Open run capacitor and open start capacitor or contacts
		2. High current until motor starts and then zero	a. Open run capacitor
		3. High current; motor hums until overload opens	a. Shorted run capacitor b. Shorted start winding c. Open run winding
AM$_3$	High current until motor starts and then normal run amps	1. No current	a. Open run winding
		2. High current until overload opens	a. Shorted run winding b. Problems in start winding circuit (check AM$_1$ & AM$_2$)

Troubleshooting ACR Electrical Systems
Unit 14

Student Supplement 2—Troubleshooting Tree for a Standing Pilot


Start
Check pilot
No
Yes
Check power at unit fan switch On then AUTO
No
Yes
Set therm for heat: Check burner
No
Yes
No
Check gas valve for voltage
Yes
Problem is in valve (Make sure valve is on)
Check to see if fan comes on
Yes
System operates normal (Finished)
No
Yes
No
Check for open in circuit to gas valve
Check valve; Replace if necessary (Finished)
Check fan for voltage
Yes
Check motor and capacitor
No
Yes
No
Check Wiring; Repair if necessary
Repair open
Check power circuit to fan; Repair open
Replace motor or capacitor
Finished
Finished
Finished
Finished

Note: If ther is a "No" at the initial "Check pilot," troubleshooting would follow the other side of the troubleshooting tree. Space does not permit its presentation.

Troubleshooting ACR System Electrical Circuits
Unit 14

Assignment Sheet 1—Identify Components on ACR System Electrical Diagrams

Name ______________________________ Overall Rating ________

Evaluation Criteria	Rating
Number of answers completed	______
Number of correct answers	______

Directions: Reference the accompanying ACR system electrical diagrams to answer the following questions.

A. What are the power sources?

____

____

____

B. What are the system loads?

____

____

____

____

____

____

C. What switches are in the contactor coil circuit?

____

____

____

D. What are the names of the motors and how many switch contacts control each motor?

______________________________ __________

______________________________ __________

______________________________ __________

E. Do the blower relay contacts control the hot leg or the neutral leg?

____

Assignment Sheet 1

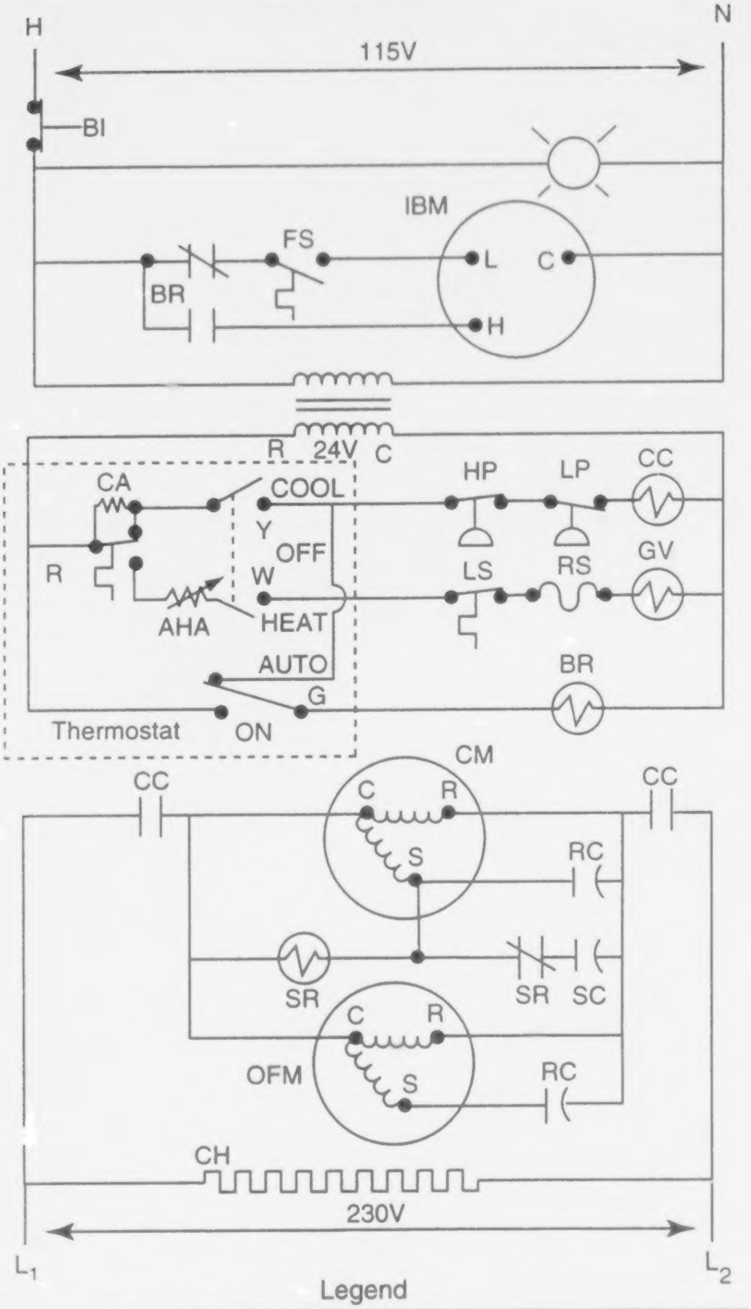
F. What loads are in series when the thermostat is calling for heating?

____

G. What load is parallel to the start relay coil?

____

Assignment Sheet 1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RS
R
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HEAT
AUTO
BR
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Thermostat
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CM
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C
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CC
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RC
SR
SR
SC
C
R
OFM
S
RC
CH
230V
L_1
L_2

Legend

AHA — Adjustable heating anticipator
BI — Blower door interlock
BR — Blower relay
CA — Cooling anticipator
CC — Cooling contactor
CH — Crankcase heater
CM — Compressor motor
FS — Fan switch
GV — Gas valve

HP — High-pressure switch
IBM — Indoor blower motor
LP — Low-pressure switch
LS — Limit switch
OFM — Outdoor fan motor
RC — Run capacitor
RS — Rollout switch
SR — Start relay
SC — Start capacitor

Troubleshooting ACR System Electrical Circuits
Unit 14

Assignment Sheet 2—Identify Component Operations From ACR System Electrical Diagrams

Name ____ Overall Rating _____

Evaluation Criteria	**Rating**
Number of answers completed	______
Number of answers correct	______

Directions: Reference the accompaning ACR system electrical diagrams to answer the following questions.

A. Assuming the blower door is closed and the light is functional, will the indoor blower motor operate if the light is not on? __________ Why or why not?

B. What effect will energizing the compressor contactor have on the crankcase heater?

C. With the thermostat calling for cooling, what effect will an open low-pressure switch have on the indoor blower motor?

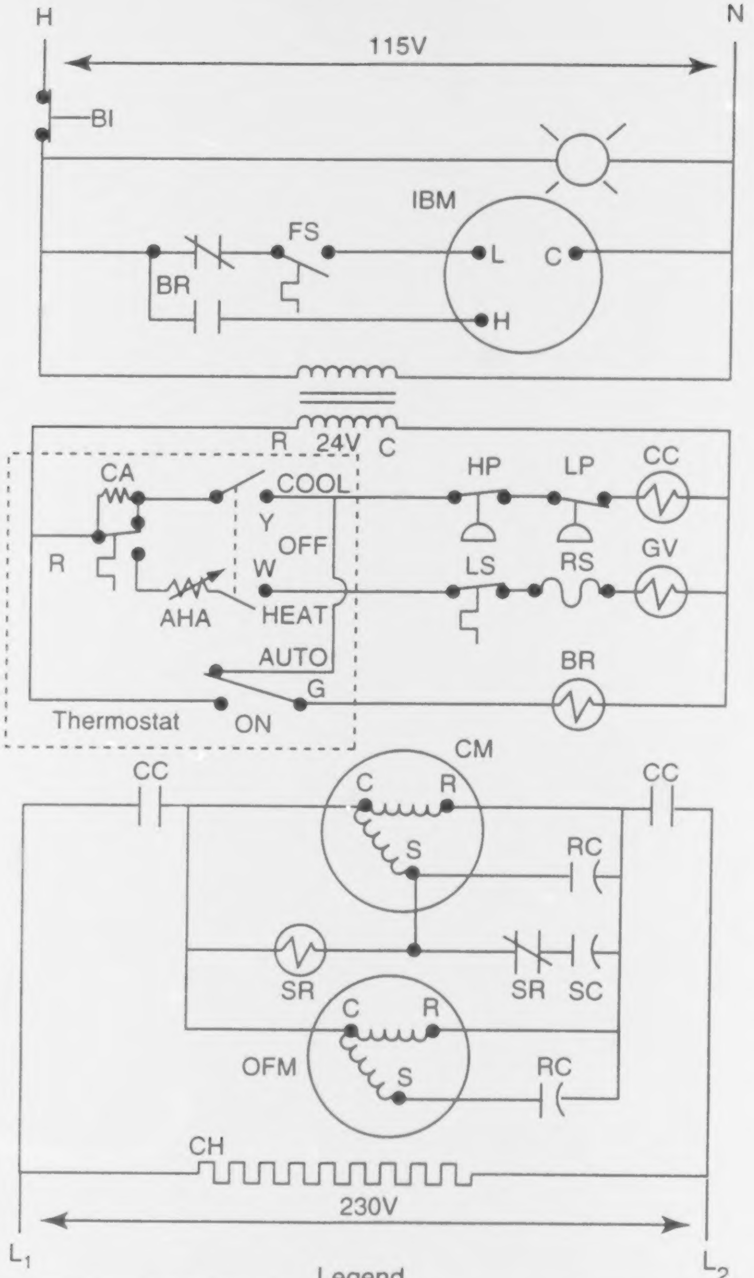
D. What is disconnected when the start relay is energized?

E. What switches must be closed to energize the indoor blower motor low-speed?

F. What switches or other components could be open if 24V is available from the transformer but is not available at the gas valve?

G. What switches could the 24V go through to reach the blower relay coil?

Assignment Sheet 2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Legend

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SC — Start capacitor

Troubleshooting ACR System Electrical Circuits
Unit 14

Assignment Sheet 3—Select Test Instruments or Procedures for Specific ACR System Troubleshooting

Name ____ Overall Rating ______

Evaluation Criteria	**Rating**
Number of questions completed	______
Number of answers correct	______

Directions: Reference the accompanying ACR system diagrams and select test instrument(s) and/or procedure(s) to answer the following questions.

Example: Is potential available to the indoor blower motor?

Turn thermostat automatic on switch to on; if blower runs voltage is available, or

Check light; if light is burning, power is available to the indoor blower motor, or

Use a voltmeter with probes at neutral and the outlet side of the blower interlock switch.

A. Is potential available to the compressor contactor contacts?

____

B. (1) Are the blower relay normally open contacts open as determined by using the hopscotch method?

____

____

____

____

(2) Are the blower relay normally open contacts open as determined by using other than the hopscotch method?

____

____

____

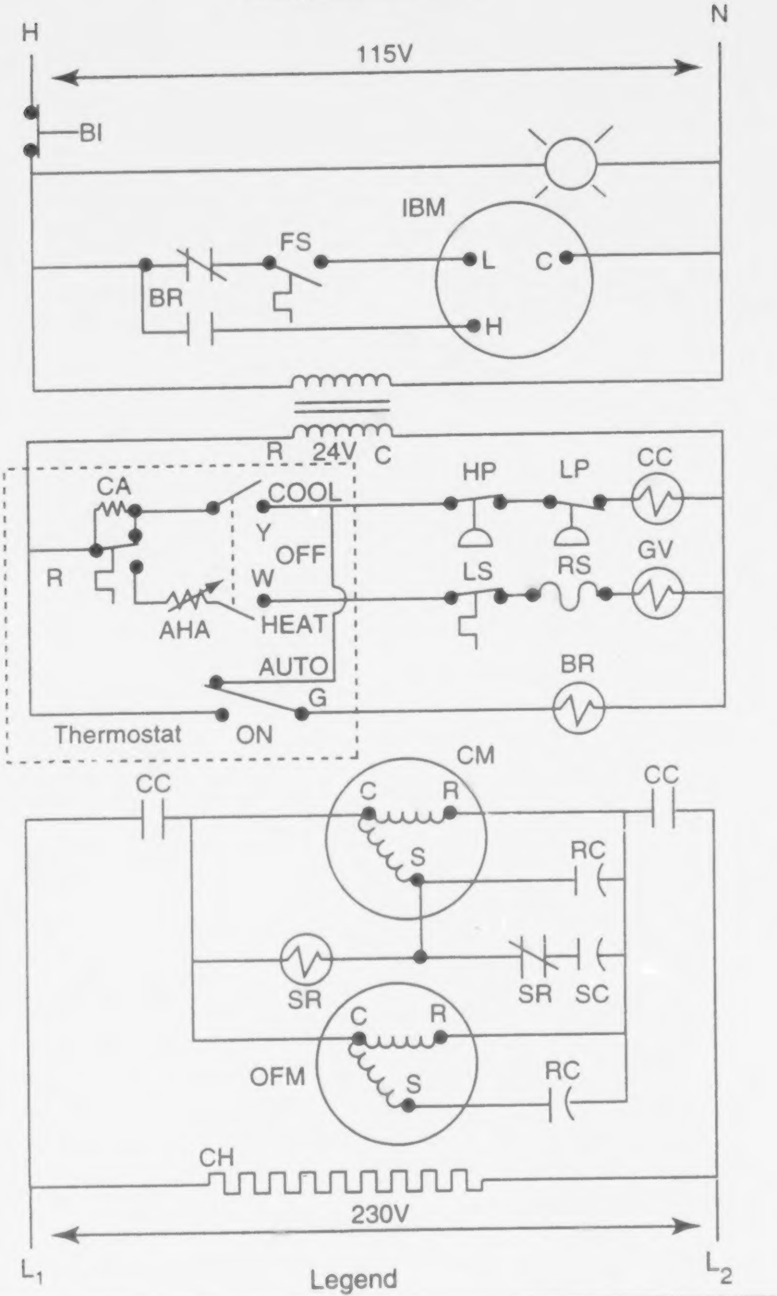
Assignment Sheet 3

C. Are the outdoor fan motor windings open?

D. Is the crankcase heater operating?

E. Will the compressor run after you find an open high pressure switch?

Assignment Sheet 3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CC
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R
W
LS
RS
AHA
HEAT
AUTO
BR
G
Thermostat
ON
CM
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OFM
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L2

Legend

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RS	— Rollout switch
SR	— Start relay
SC	— Start capacitor

Troubleshooting ACR System Electrical Circuits
Unit 14

Assignment Sheet 4—Solve ACR Electrical Troubleshooting Problems

Name ______________________________ Overall Rating _____

Evaluation Criteria	Rating
Number of answers completed	______
Number of answers correct	______

Directions: Reference the accompanying ACR system electrical diagrams to solve the following problems.

A. A customer complains of no cooling. Upon arrival at the location, you observe that the thermostat is set to call for cooling and automatic fan operation, but nothing is running. You set the thermostat fan switch to the ON position and the indoor blower motor starts and runs normally.

What specific component could cause the conditions observed?

What would you recommend to correct the problem?

B. A customer complains of no cooling. Upon arrival at the location, you observe both fans running, but the compressor is not running.

Assuming there are no broken wires, what components could cause the problem?

C. A customer complains of no heat. Upon arrival at the location, you observe that the thermostat is set to call for heat but nothing is running. A voltmeter check reads 24V from W on the thermostat to C on the transformer, but a voltmeter check at the gas valve reads zero volts.

Excluding wiring or connections, what components could fail and cause the conditions observed?

Assignment Sheet 4

D. A customer complains of no heat. Upon arrival at the location, you observe that the thermostat is set to call for heat but nothing is running. You turn the fan switch to the ON position, but nothing happens. You open the electrical panel and observe the power light on.

What component should you check next?

____

E. A customer complains of no heat. Upon arrival at the location, you observe that the thermostat is set to call for heat, but nothing is running. You set the fan switch to the ON position and the blower runs. Using the hopscotch method, you determine that the limit switch is open even though the furnace is obviously not overheated.

What can you do to determine if the furnace will work if you replace the limit switch?

____

____

____

F. A customer complains of not enough cooling. Upon arrival at the location, you observe that the outdoor condensing unit is cycling on and off approximately every three to four minutes. After cleaning a dirty condenser coil, the system has normal operating pressures, but continues to cycle on and off. You determine that the high-pressure switch has failed.

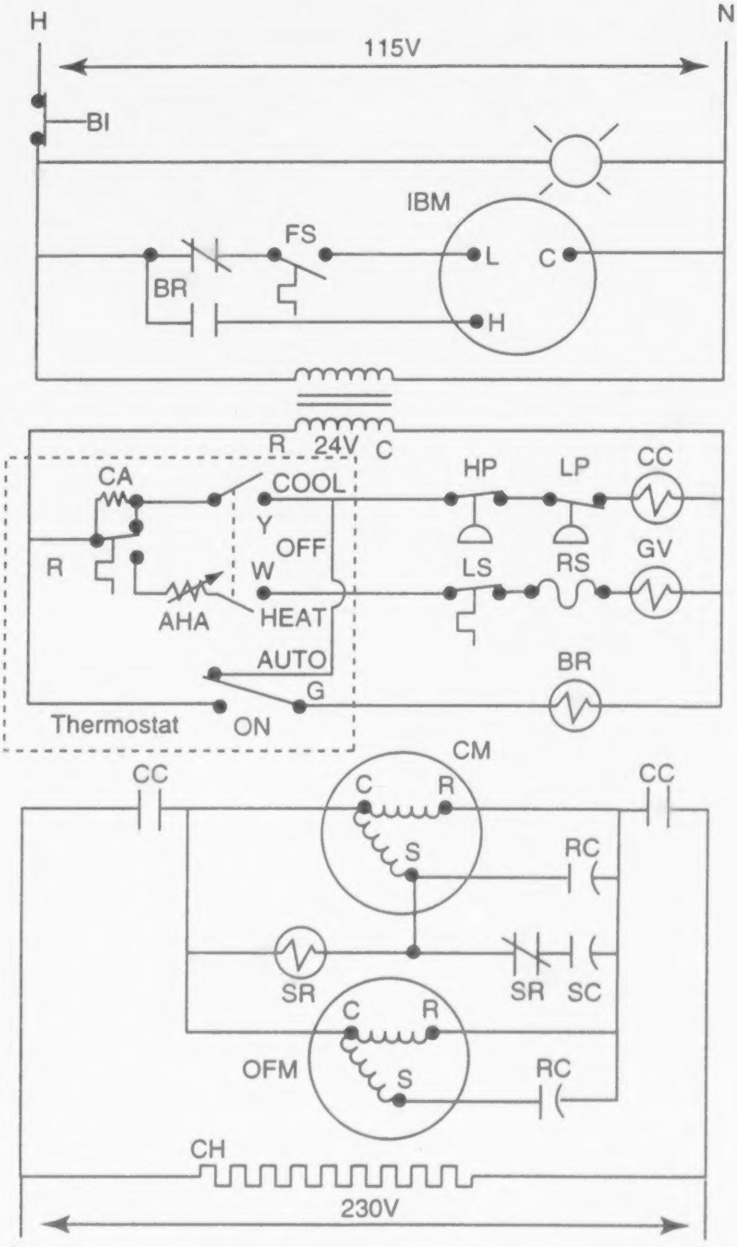
What could you do to make the system operational until you can obtain a new high-pressure switch?

____

____

____

Assignment Sheet 4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Y
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R
W
AHA
HEAT
AUTO
G
Thermostat
ON
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LP
CC
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RS
GV
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CM
CC
C
R
CC
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RC
SR
SR
SC
C
R
OFM
S
RC
CH
230V
L_1
L_2

Legend

AHA	— Adjustable heating anticipator	HP	— High-pressure switch
BI	— Blower door interlock	IBM	— Indoor blower motor
BR	— Blower relay	LP	— Low-pressure switch
CA	— Cooling anticipator	LS	— Limit switch
CC	— Cooling contactor	OFM	— Outdoor fan motor
CH	— Crankcase heater	RC	— Run capacitor
CM	— Compressor motor	RS	— Rollout switch
FS	— Fan switch	SR	— Start relay
GV	— Gas valve	SC	— Start capacitor

Troubleshooting ACR System Electrical Circuits
Unit 14

Job Sheet 1—Troubleshoot Series Electrical Circuits on Selected ACR Equipment

Name ______________________________ Attempt Number _____

Date ______________________________ Overall Rating _______

Evaluation Criteria	Rating
Equipment operated for evaluation	______
Test instruments/procedures used to identify circuit problems	______
Corrective action recommended and recorded	______

A. Tools and materials

Trainer or selected ACR equipment w/series electrical circuits
ACR technician's hand tools
Safety glasses
Test instruments as required

B. Procedure

Note: Your instructor will provide you with series circuit(s) with faults inserted.

☐ 1. Put on safety glasses.

☐ 2. Remove panels or covers as needed to access components.

☐ 3. Use electrical diagrams and any other available information about this equipment to identify circuit components and their normal operation.

☐ 4. Operate circuit or equipment and observe normal operation.

☐ 5. Have your instructor insert fault(s).

☐ 6. Observe operation of equipment or circuit and compare with normal operation.

☐ 7. Select appropriate test instrument(s) and procedure to evaluate the condition of the equipment.

☐ 8. Use your selected test instrument(s) and procedure to determine the cause of the circuit problem(s), and record your findings.

____

____

☐ 9. If you find an open, jumper the open to determine if there are any other problems.

Note: While open loads are not normally jumpered, when loads are in series, an open load can be jumpered.

Job Sheet 1

☐ 10. Record what corrective action you would recommend to make the circuit or equipment functional.

____

____

☐ 11. Have your instructor evaluate your findings.

☐ 12. Repeat the procedure for other problems as directed by your instructor.

☐ 13. Shut down equipment and return tools and test instruments to proper storage.

Comments: ____

____

____

____

Troubleshooting ACR System Electrical Circuits
Unit 14

Job Sheet 2—Troubleshoot Parallel Electrical Circuits on Selected ACR Equipment

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Equipment operated for evaluation	______
Test instruments/procedures used to identify circuit problems	______
Corrective action recommended and recorded	______

A. Tools and materials

Trainer or selected ACR equipment w/parallel electrical circuits
ACR technician's hand tools
Safety glasses
Test instruments as required

B. Procedure

Note: Your instructor will provide you with parallel circuit(s) with faults inserted.

☐ 1. Put on safety glasses.

☐ 2. Remove panels or covers as needed to access components.

☐ 3. Use electrical diagrams and any other available information about this equipment to identify circuit components and their normal operation.

☐ 4. Operate circuit or equipment and observe normal operation.

☐ 5. Have your instructor insert fault(s).

☐ 6. Observe operation of equipment or circuit and compare with normal operation.

☐ 7. Select appropriate test instrument(s) and procedure to evaluate the condition of the equipment.

☐ 8. Use your selected test instrument(s) and procedure to determine the cause of the circuit problem(s), and record your findings.

____

____

☐ 9. If you find an open switch, safety device, or wire, jumper the open to determine if there are any other problems.

CAUTION: Jumpering an open load in a parallel circuit creates a direct short and will trip safetys and possibly damage components.

Job Sheet 2

☐ 10. Record what corrective action you would recommend to make the circuit or equipment functional.

☐ 11. Have your instructor evaluate your findings.

☐ 12. Repeat the procedure for other problems as directed by your instructor.

☐ 13. Shut down equipment and return tools and test instruments to proper storage.

Comments:

Troubleshooting ACR System Electrical Circuits
Unit 14

Job Sheet 3—Troubleshoot Series-Parallel Electrical Circuits on Selected ACR Equipment

Name ______________________________ Attempt Number _____

Date ______________________________ Overall Rating________

Evaluation Criteria	**Rating**
Equipment operated for evaluation	______
Test instruments/procedures used to identify circuit problems	______
Corrective action recommended and recorded	______

A. Tools and materials

Trainer or selected ACR equipment w/series-parallel electrical circuits
ACR technician's hand tools
Safety glasses
Test instruments as required

B. Procedure

Note: Your instructor will provide you with series-parallel circuit(s) with faults inserted.

☐ 1. Put on safety glasses.

☐ 2. Remove panels or covers as needed to access components.

☐ 3. Use electrical diagrams and any other available information about this equipment to identify circuit components and their normal operation.

☐ 4. Operate circuit or equipment and observe normal operation.

☐ 5. Have your instructor insert fault(s).

☐ 6. Observe operation of equipment or circuit and compare with normal operation.

☐ 7. Select appropriate test instrument(s) and procedure to evaluate the condition of the equipment.

☐ 8. Use your selected test instrument(s) and procedure to determine the cause of the circuit problem(s), and record your findings.

____

____

☐ 9. If you find an open switch, safety device, or wire, jumper the open to determine if there are any other problems.

CAUTION: Jumpering an open load in a parallel circuit creates a direct short and will trip safetys and possibly damage components.

Job Sheet 3

☐ 10. Record what corrective action you would recommend to make the circuit or equipment functional.

____

____

☐ 11. Have your instructor evaluate your findings.

☐ 12. Repeat the procedure for other problems as directed by your instructor.

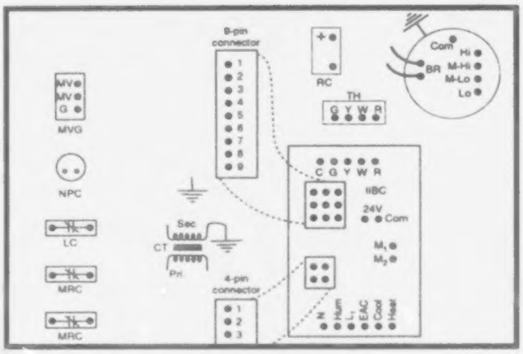
☐ 13. Shut down equipment and return tools and test instruments to proper storage.

Comments: ______________________________________

____

____

____



ACR System Wiring Diagrams

Unit 15

Objective Sheet

Unit Objective

After completing this unit, the student should be able to draw pictorials and ladder schematics for refrigerators, a window air conditioner, standard upflow and downflow gas furnaces, an electric furnace, and a condensing unit and an air handler. The student should also be able to observe a refrigerator, a window air conditioner, and a heating/cooling unit and draw ladder schematics for them. The student should demonstrate these competencies by completing the activities in the assignment and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Complete statements about terms and definitions related to ACR system wiring diagrams.
2. Complete statements about guidelines for drawing system diagrams.
3. Match ACR components with their schematic symbols.
4. Match switches in ACR systems with their schematic symbols.
5. Match solid-state components with their schematic symbols.
6. Select true statements about the procedure for drawing typical ACR system wiring diagrams.
7. Draw wiring diagrams for a refrigerator with a coil-type current relay. (Assignment Sheet 1)
8. Draw wiring diagrams for a refrigerator with a solid-state start relay. (Assignment Sheet 2)
9. Draw wiring diagrams for a window air conditioner. (Assignment Sheet 3)

Objective Sheet

10. Draw wiring diagrams for a standard upflow gas furnace. (Assignment Sheet 4)
11. Draw wiring diagrams for a standard downflow gas furnace. (Assignment Sheet 5)
12. Draw wiring diagrams for a multiposition gas furnace with an integrated control board. (Assignment Sheet 6)
13. Draw wiring diagrams for a condensing unit. (Assignment Sheet 7)
14. Draw wiring diagrams for an electric furnace. (Assignment Sheet 8)
15. Draw wiring diagrams for a condensing unit and an air handler. (Assignment Sheet 9)
16. Draw a ladder schematic for a domestic refrigerator. (Assignment Sheet 10)
17. Observe a domestic refrigerator and draw a ladder schematic of its electrical circuits. (Job Sheet 1)
18. Observe a window air conditioner and draw a ladder schematic of its electrical circuits. (Job Sheet 2)
19. Observe a heating/cooling system with 24V controls and draw a ladder schematic of its electrical circuits. (Job Sheet 3)

ACR System Wiring Diagrams
Unit 15

Information Sheet

1. **Terms and definitions**

   a. **Ladder schematic diagram**—A diagram which resembles a ladder and which shows electrical components as symbols, how they function, and their order of operation

   b. **Pictorial diagram**—A diagram which shows pictures or representative drawings of electrical components in their approximate locations in the equipment

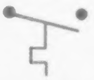
   c. **Legend**—The descriptive list of the components in a wiring diagram

2. **Guidelines for drawing system diagrams**

   a. When system wiring diagrams are gone or unreadable, a service technician must sometimes recreate a wiring diagram before troubleshooting or repairing system wiring.

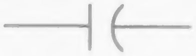
   b. Technicians usually choose to draw a schematic diagram because it shows the functions of components and order of operations.

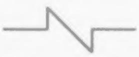
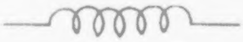
   c. Pictorial diagram graphics or symbols must be converted to schematic symbols in a schematic drawing.

   Example: A refrigerator thermostat may be shown on a pictorial simply as a set of contacts —| |— ; on a schematic the thermostat would be shown as a temperature sensing symbol 

   d. If no pictorial is available or there could be some confusion over the identity of a component, it will be labeled or identifed in a legend.

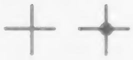
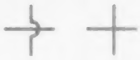
3. **ACR components and their schematic symbols**

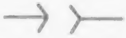
   a. Capacitor 

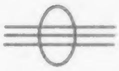
   b. Coil  or 

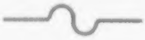
   Note: The symbol above left represents a relay magnetic coil or a solenoid; the right symbol is used to represent not only relays but motor windings and other types of coils.

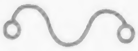
Information Sheet

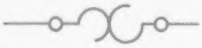
c. Conductors  or 

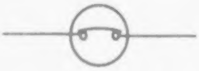
d. Connectors 

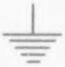
e. Multiple conductor cable 

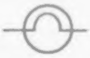
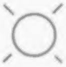
f. Fuse 

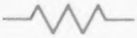
g. Fusible link 

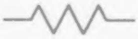
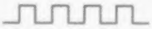
h. Thermal overload 

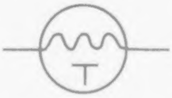
i. Bimetal disc 

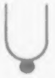
j. Ground connection 

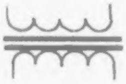
k. Light  or 

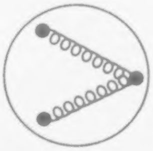
l. Resistor 

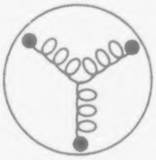
m. Resistance heater  or 

n. Thermistor 

o. Thermocouple 

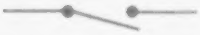
p. Transformer 

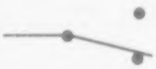
q. Single-phase motor 

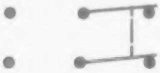
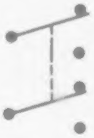
r. Three-phase motor 

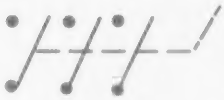
Information Sheet

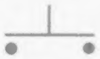
4. **ACR system switches and their schematic symbols**

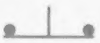
   a. SPST switch 

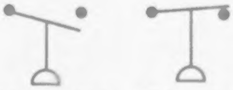
   b. SPDT switch 

   c. DPDT switch  or 

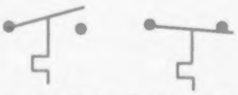
   d. TPST Disconnect 

   e. Push button NO 

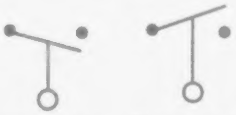
   f. Push button NC 

   g. Pressure switches 

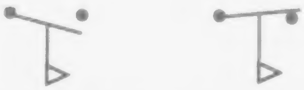
   Close on rise Open on rise

   h. Temperature switches 

   Close on fall Open on fall

   i. Liquid level switches 

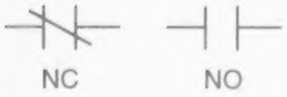
   Close on rise Close on fall

   j. Flow switches 

   Close on increase Open on increase

Information Sheet

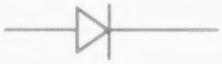
k. Contacts



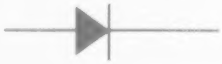
Note: In electronics, the symbol for a condenser or capacitor resembles the symbol for NO contacts.

5. **Solid-state components and their schematic symbols**

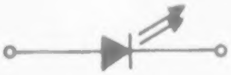
a. Diode



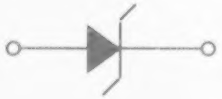
or



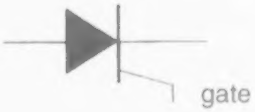
b. LED



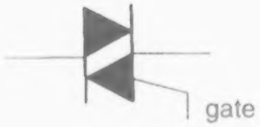
c. Zener diode



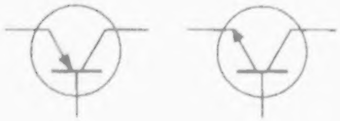
d. SCR



e. Triac



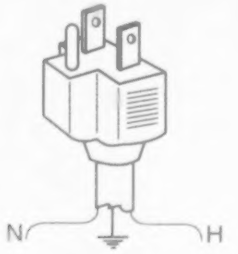
f. Transistor

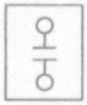


Information Sheet

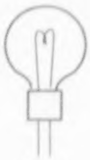
6. **Procedure for drawing typical ACR system wiring diagrams**

   a. Components of a refrigerator are depicted below in sketches such as would be found on a pictorial or drawn by a technician.

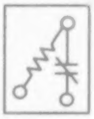




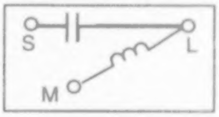
Doorlight switch



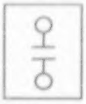
Door light



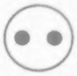
Bimetal overload



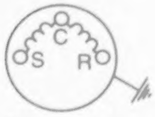
Current-type start relay



Cold control (Thermostat)



Start capacitor



Compressor motor

   b. Completing a pictorial diagram of the refrigerator in item "a" could be accomplished using the following or a similar procedure:

      (1) Connect the thermostat in series with L on the relay and the hot leg of the power supply.

      (2) Connect S on the relay to the S terminal on the compressor motor.

      (3) Connect M on the relay to the R terminal on the compressor motor.

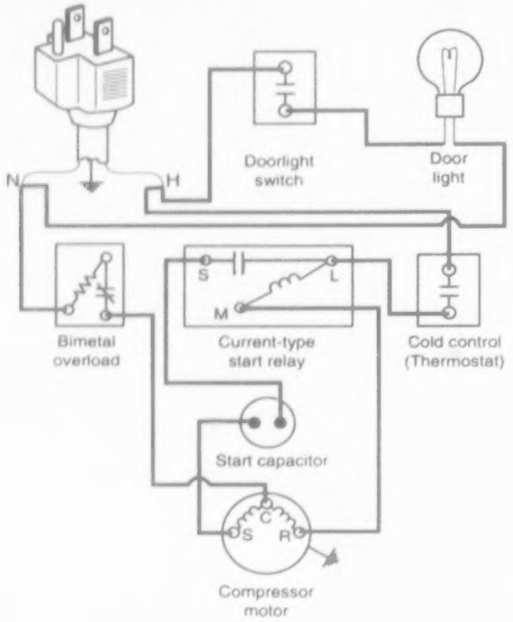
      (4) Connect the C terminal on the compressor motor to the neutral leg of the power supply.

      (5) Connect one side of the door light to neutral.

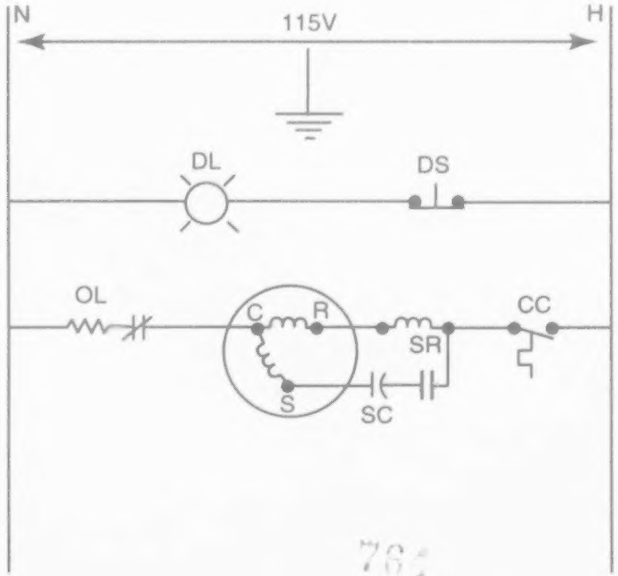
      (6) Connect the door light switch in series with the hot leg of the power supply and the door light.

Information Sheet

c. When completed, a technician's pictorial diagram should have pictures or sketches of component symbols with connecting wiring drawn in.


N
H
Doorlight switch
Door light
Bimetal overload
S
L
M
Current-type start relay
Cold control (Thermostat)
Start capacitor
C
S
R
Compressor motor

d. The technician would reference the pictorial to draw a matching ladder schematic like the following:


N
115V
H
DL
DS
OL
C
R
SR
CC
S
SC

Note: Notice that the symbols used in the ladder schematic not only are different from pictorial symbols, but show how the components operate.

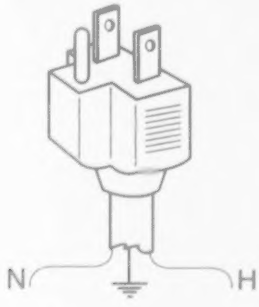
ACR System Wiring Diagrams
Unit 15

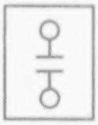
Assignment Sheet 1—Draw Wiring Diagrams for a Refrigerator With a Coil-Type Current Relay

Name ______________________________ Overall Rating ______

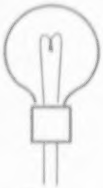
Evaluation Criteria	**Rating**
Pictorial properly completed	______
Ladder schematic properly completed	______

Directions: Use the following graphics and procedure to complete a pictorial diagram, and then use the pictorial as a guide to complete a ladder schematic.

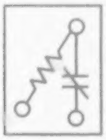




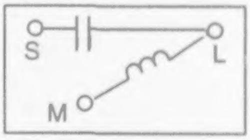
Doorlight switch



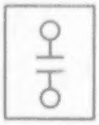
Door light



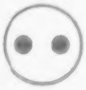
Bimetal overload



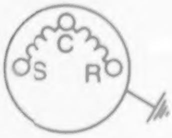
Current-type start relay



Cold control (Thermostat)



Start capacitor



Compressor motor

Assignment Sheet 1

Procedure

1. Connect the thermostat in series with L on the relay and the hot leg of the power supply.
2. Connect the start capacitor in series with S on the relay and the S terminal on the compressor motor.
3. Connect M on the relay to the R terminal on the compressor motor.
4. Connect the overload in series with C on the compressor motor and the neutral leg of the power supply.
5. Connect one side of the door light to neutral.
6. Connect the door light switch in series with the hot leg of the power supply and the door light.
7. Reference your completed pictorial to draw a matching ladder schematic in the space below.

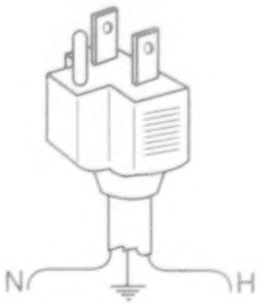
ACR System Wiring Diagrams
Unit 15

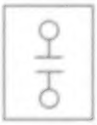
Assignment Sheet 2—Draw Wiring Diagrams for a Refrigerator With a Solid-State Start Relay

Name ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Pictorial properly completed	______
Ladder schematic properly completed	______

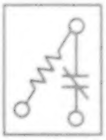
Directions: Use the following graphics and procedure to complete a pictorial diagram and then use the pictorial as a guide to complete a ladder schematic.



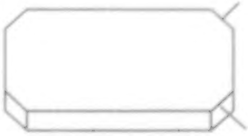


Doorlight switch

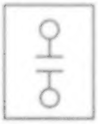
Door light



Bimetal overload

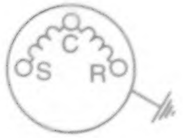


Solid-state relay



Cold control (Thermostat)

Start capacitor



Compressor motor

Assignment Sheet 2

Procedure

1. Connect the thermostat in series with R on the compressor and the hot leg of the power supply.
2. Connect one lead of the solid-state relay to the thermostat where the wire from R on the compressor connects.
3. Connect the start capacitor in series with the other lead on the relay and the S terminal on the compressor motor.
4. Connect the overload in series with the C terminal on the compressor motor and the neutral leg of the power supply.
5. Connect one side of the door light to neutral.
6. Connect the door light switch in series with the hot leg of the power supply and the door light.
7. Reference your completed pictorial to draw a matching ladder schematic in the space below.

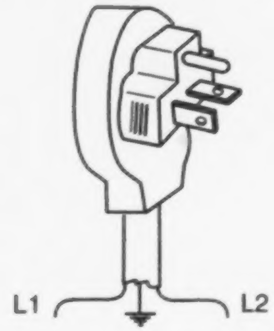
ACR System Wiring Diagrams
Unit 15

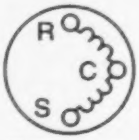
Assignment Sheet 3—Draw Wiring Diagrams for a Window Air Conditioner

Name ______________________________ Overall Rating ______

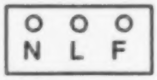
Evaluation Criteria	**Rating**
Pictorial properly completed	______
Ladder schematic properly completed	______

Directions: Use the following graphics and procedure to complete a pictorial diagram, and then use the pictorial as a guide to complete a ladder schematic.

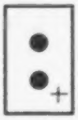




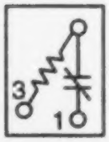
Fan motor



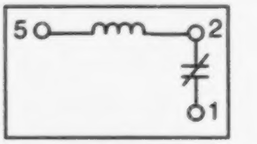
Switch



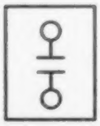
Run capacitor



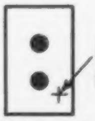
Bimetal overload



Potential Relay

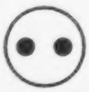


Cold control (Thermostat)

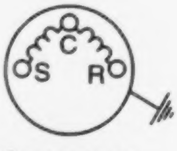


Identified terminal

Run Capacitor



Start capacitor



Compressor motor

Assignment Sheet 3

Procedure

1. Connect L_2 on the power cord to N on the switch.

2. Connect L on the switch to the thermostat.

3. Connect the overload in series with the thermostat and the R terminal on the compressor motor.

4. Connect the compressor run capacitor in series with 1 on the overload and the S terminal on the compressor motor with the identified terminal connected to the overload.

5. Connect L_1 on the power cord to the C terminal on the compressor, the C terminal on the fan motor, and 5 on the potential relay.

6. Connect the start capacitor to 1 on the potential relay and to the identified terminal on the compressor run capacitor.

7. Connect 2 on the potential relay to the side of the compressor run capacitor connected to the S terminal.

8. Connect F on the switch to the R terminal on the fan motor.

9. Connect the fan motor run capacitor in series with F on the switch and the S terminal on the fan motor.

10. Reference your completed pictorial to draw a matching ladder schematic in the space on the opposite page.

Assignment Sheet 3

ACR System Wiring Diagrams
Unit 15

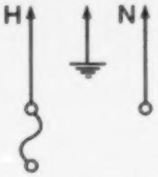
Assignment Sheet 4—Draw Wiring Diagrams for a Standard Upflow Gas Furnace

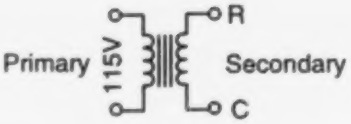
Name ______________________________ Overall Rating ______

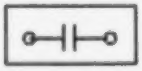
Evaluation Criteria	**Rating**
Pictorial properly drawn	______
Ladder schematic properly drawn	______

Directions: Use the following graphics and procedure to complete a pictorial diagram, and then use the pictorial as a guide to complete a ladder schematic.

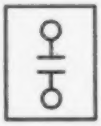
To power supply



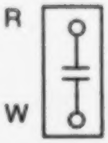




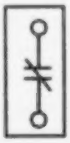
Blower interlock switch



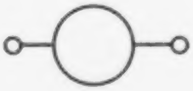
Fan control



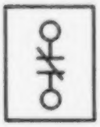
Thermostat



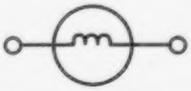
Limit control



115V Indoor fan motor



Flame rollout switch



Main gas valve, 24V

Assignment Sheet 4

Procedure

1. Connect the fuse to one side of the blower interlock switch.
2. Connect one lead of the transformer primary winding to the other side of the blower interlock switch.
3. Connect the other lead of the transformer primary to the neutral leg of the power supply.
4. Connect the fan control in series with the blower interlock switch and one side of the fan motor.
5. Connect the other side of the fan motor to neutral.
6. Connect R on the thermostat to R on the transformer secondary.
7. Connect the limit control and the flame rollout switch in series with W on the thermostat and one side of the gas valve.
8. Connect the other side of the gas valve to C on the transformer secondary.
9. Reference your completed pictorial to draw a matching ladder schematic in the space below.

ACR System Wiring Diagrams
Unit 15

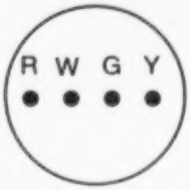
Assignment Sheet 5—Draw Wiring Diagrams for a Standard Downflow Gas Furnace

Name ______________________________ __________ Overall Rating ______

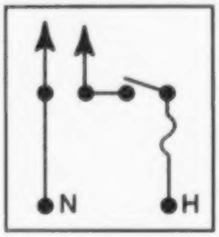
Evaluation Criteria	**Rating**
Pictorial properly drawn	______
Ladder schematic properly drawn	______

Directions: Use the following graphics and procedure to complete a pictorial diagram, and then use the pictorial as a guide to complete a ladder schematic.

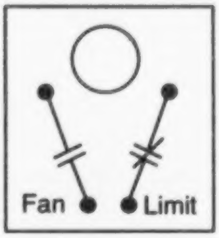
Thermostat



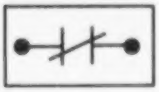
Disconnect



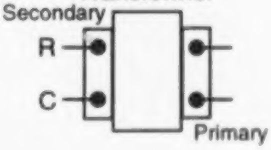
Fan and limit



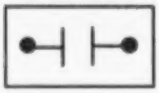
Upper limit



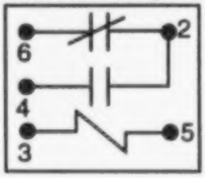
Transformer



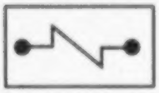
Blower interlock switch



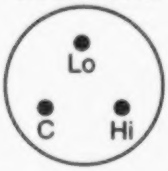
Blower relay



Gas valve



Blower motor



Assignment Sheet 5

Procedure

1. Connect the hot leg of the disconnect to the blower interlock switch.
2. Connect the upper limit control in series with one side of the transformer primary and the blower interlock switch.
3. Connect the other lead of the transformer primary to neutral on the disconnect.
4. Connect R on the transformer secondary to R on the thermostat.
5. Connect the limit control of the combination fan/limit in series with W on the thermostat and one side of the gas valve.
6. Connect the other side of the gas valve to C on the transformer secondary.
7. Connect G on the thermostat to one side of the blower relay coil.
8. Connect the other side of the blower relay coil to C on the transformer secondary.
9. Connect 2 on the blower relay to the blower interlock switch opposite to the disconnect.
10. Connect the fan switch in the combination fan/limit in series with Lo on the blower motor and 6 on the blower relay.
11. Connect 4 on the relay to Hi on the blower motor.
12. Connect C on the blower motor to neutral.
13. Reference your completed pictorial to draw a matching ladder schematic in the space on the opposite page.

Assignment Sheet 5

Ladder Schematic

ACR System Wiring Diagrams
Unit 15

Assignment Sheet 6—Draw Wiring Diagrams for a Multiposition Gas Furnace With an Integrated Control Board

Name ______________________________ Overall Rating _____

Evaluation Criteria	**Rating**
Pictorial properly drawn	______
Ladder schematic properly drawn	______

Directions: Use the following graphics and procedure to complete a pictorial diagram.

Note: Because of the space required to draw the pictorial, the components are shown on the final page of this assignment sheet.

Procedure

1. Connect blower door interlock in series with the fuse and L_1 on the IIBC.
2. Connect the neutral side of the disconnect to N on the IIBC.
3. Connect Lo on the IBM to Heat on the IIBC.
4. Connect Hi on the indoor blower motor to Cool on the IIBC.
5. Connect other speed leads to M_1 and M_2 on the IIBC.
6. Connect Com on the IBM to N on the IIBC.
7. Connect the Br (brown) wires on the IBM to the run capacitor.
8. Connect the primary of the control transformer to N and L_1 on the IIBC.
9. Connect the secondary of the control transformer to the 24V terminals on the IIBC with Com to grounded side.
10. Connect all corresponding letters between the thermostat and and IIBC.
11. Connect 2 and 3 on the 9-pin connector to the MV terminals on the main gas valve.
12. Connect 4 and 5 on the 9-pin connector to the negative pressure control.

Assignment Sheet 6

13. Connect the limit control and three rollout controls in series with 6 and 7 on the 9-pin connector.

14. Connect 9 on the 9-pin connector to ground.

15. Connect 1 and 2 on the 4-pin connector to the igniter element.

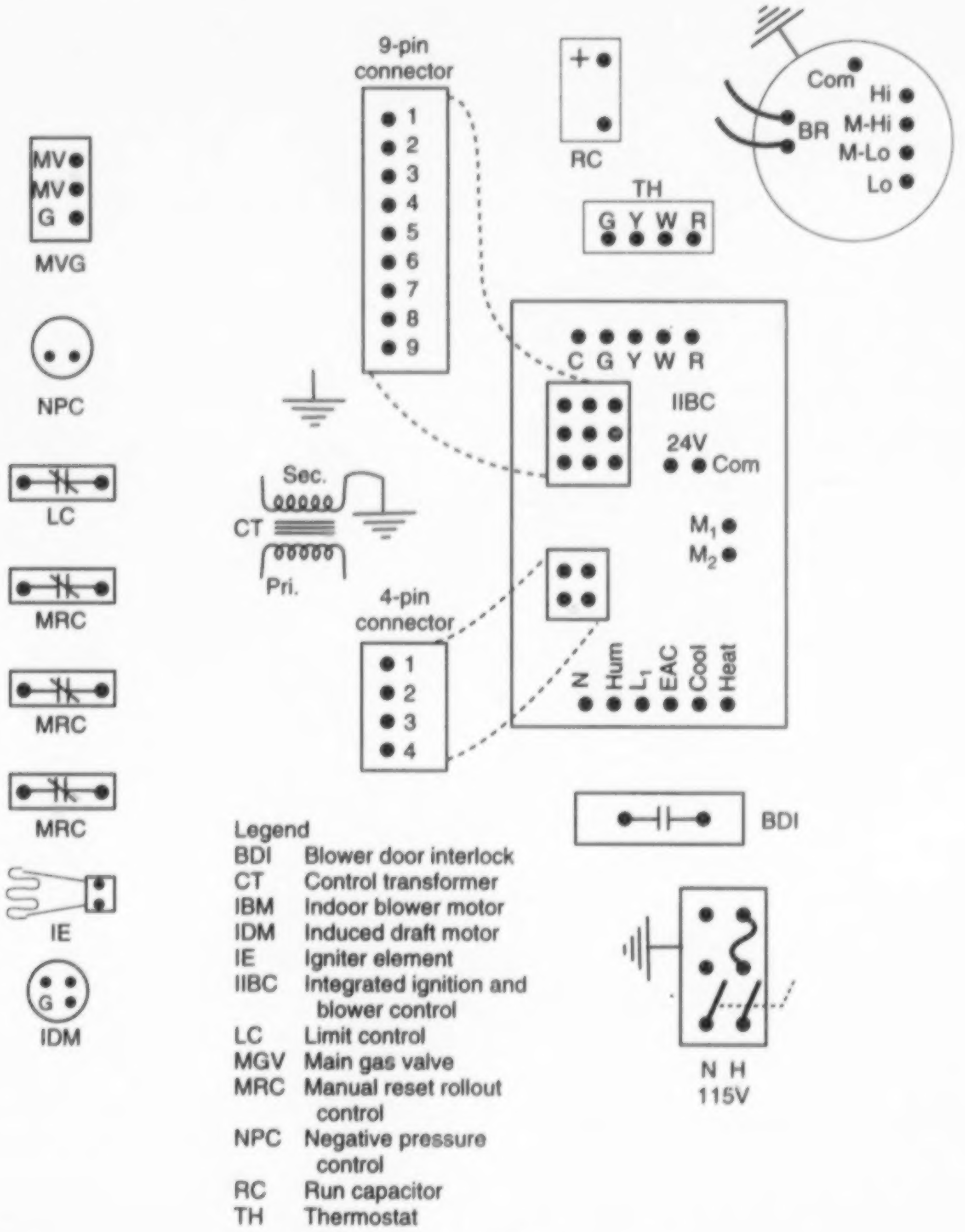
16. Connect 3 and 4 on the 4-pin connector to the induced draft motor.

17. Connect G on the IDM to G on the main gas valve to 24V common on the IIBC.

Note: After completing a pictorial, a technician would usually draw a ladder schematic, but in this case, without manufacturer's literature, the technician cannot determine what goes on inside the IIBC board.

Assignment Sheet 6

Multiposition Gas Furnace With Integrated Ignition and Blower Control


9-pin connector
1
2
3
4
5
6
7
8
9
+
RC
Com
Hi
BR
M-Hi
M-Lo
Lo
TH
G Y W R
MV
MV
G
MVG
NPC
C G Y W R
IIBC
24V
Com
Sec.
CT
Pri.
M1
M2
LC
MRC
MRC
MRC
4-pin connector
1
2
3
4
N
Hum
L1
EAC
Cool
Heat
BDI
IE
G
IDM
N H
115V

Legend

BDI	Blower door interlock
CT	Control transformer
IBM	Indoor blower motor
IDM	Induced draft motor
IE	Igniter element
IIBC	Integrated ignition and blower control
LC	Limit control
MGV	Main gas valve
MRC	Manual reset rollout control
NPC	Negative pressure control
RC	Run capacitor
TH	Thermostat

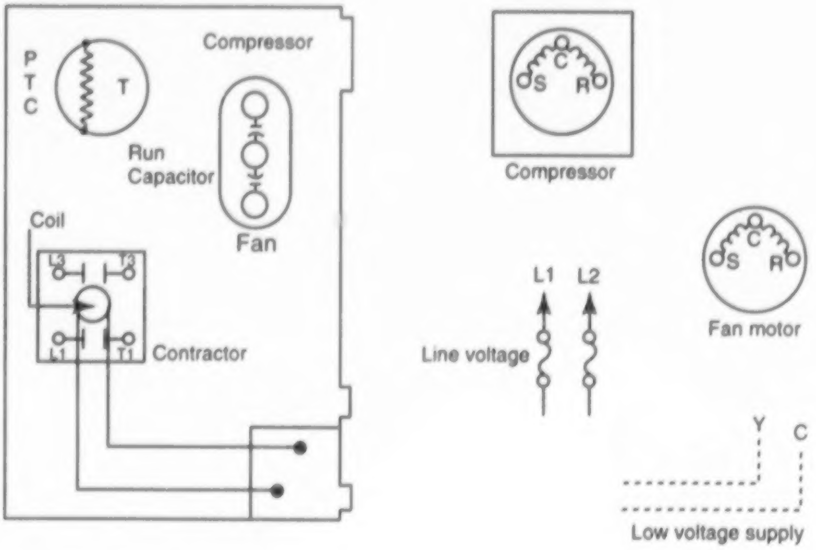
ACR System Wiring Diagrams
Unit 15

Assignment Sheet 7—Draw Wiring Diagrams for a Condensing Unit

Name ____ Overall Rating ______

Evaluation Criteria	**Rating**
Pictorial properly drawn	______
Ladder schematic properly drawn	______

Directions: Use the following graphics and procedure to complete a pictorial diagram. Draw connecting wiring through the indicated openings in the electrical control box. Use your pictorial as a guide to complete a ladder schematic.


P
T
C
T
Compressor
Run
Capacitor
Fan
Coil
L3
T3
L1
T1
Contractor
C
S
R
Compressor
C
S
R
Fan motor
L1
L2
Line voltage
Y
C
Low voltage supply

Assignment Sheet 7

Procedure

1. Connect low voltage supply to low voltage leads from the contactor.
2. Connect the line voltage fuses to L_1 and L_3 on the contactor.
3. Connect PTC start assist to common and compressor terminals on the run capacitor.
4. Connect T_1 to common on the run capacitor.
5. Connect T_3 to C on the compressor motor and to C on the fan motor.
6. Connect the compressor terminal on the run capacitor to S on the compressor motor.
7. Connect common on the run capacitor to R on the compressor motor and to R on the fan motor.
8. Connect the fan terminal on the run capacitor to S on the fan motor.
9. Reference your completed pictorial to draw a matching ladder schematic in the space below.

ACR System Wiring Diagrams
Unit 15

Assignment Sheet 8—Draw Wiring Diagrams for an Electric Furnace

Name ______________________________ Overall Rating _____

Evaluation Criteria	**Rating**
Pictorial properly drawn	_____
Ladder schematic properly drawn	_____

Directions: Use the following procedure to complete a pictorial and then use the pictorial as a guide to complete a ladder schematic. Pictorial components and a blank page for a ladder schematic are on separate pages so you can keep the finished pictorial in full view to help you more easily draw the ladder schematic.

Procedure

1. Connect L_1 of circuit 1 to fuse 1.
2. Connect L_2 of circuit 1 to fuse 2.
3. Connect L_1 of circuit 2 to fuse 3.
4. Connect L_2 of circuit 2 to fuse 4.
5. Connect blower interlock switch in series with fuse 2 and C on the blower motor.
6. Connect fuse 1 to 2 on the blower relay.
7. Connect fan control in series with 6 on the blower relay and L on the blower motor.
8. Connect 4 on the blower relay to H on the blower motor.
9. Connect the RH_1 contacts on the sequencer in series with fuse 2 and one side of the RH_1 heating element.
10. Connect the other side of the RH_1 heating element to fuse 1.
11. Connect the RH_2 contacts in series with fuse 3 and one side of the RH_2 heating element.
12. Connect the other side of the RH_2 heating element to fuse 4.

Assignment Sheet 8

13. Connect the auxillary contacts on the sequencer in series with fuse 3 and one side of the RH_3 heating element.

14. Connect the other side of the RH_3 heating element to the end of the RH_2 heating element which is connected to fuse 4.

15. Connect L_1 on the transformer to fuse 1.

16. Connect L_2 on the transformer to the side of the blower interlock switch that is connected to C on the blower motor.

17. Connect all corresponding letters between the thermostat and the terminal board.

18. Connect both corresponding letters between the transformer and the terminal board.

19. Connect W_1 on the terminal board to one side of Heater 1 on the sequencer.

20. Connect W_2 on the terminal board to one side of Heater 2 on the sequencer.

21. Connect the outdoor thermostat in series with the other side of Heater 2 on the sequencer and C on the terminal board.

22. Connect the other side of Heater 1 on the sequencer to the side of the outdoor thermostat that is connected to C on the terminal board.

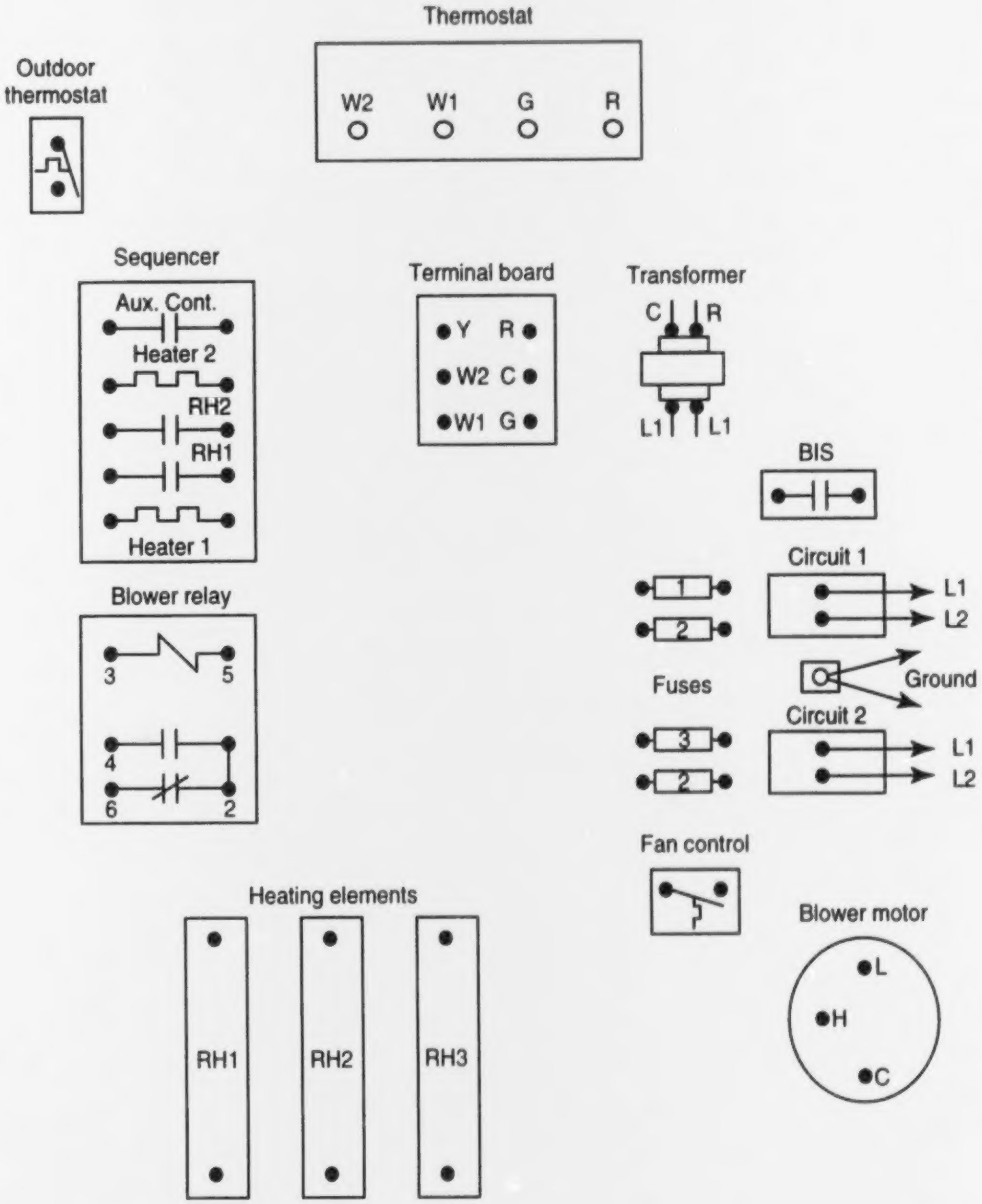
23. Connect G on'the terminal board to 5 on the blower relay.

24. Connect 3 on the blower relay to the side of Heater 1 that is connected to the outdoor thermostat.

25. Reference your completed pictorial to draw matching ladder schematics on the page provided.

    Note: Remember that each separate power supply circuit will require a separate ladder schematic.

Assignment Sheet 8


Thermostat
W2
W1
G
R
Outdoor thermostat
Sequencer
Aux. Cont.
Heater 2
RH2
RH1
Heater 1
Terminal board
Y
R
W2
C
W1
G
Transformer
C
R
L1
L1
BIS
Circuit 1
1
2
L1
L2
Fuses
Ground
Circuit 2
3
2
L1
L2
Blower relay
3
5
4
6
2
Fan control
Heating elements
RH1
RH2
RH3
Blower motor
L
H
C

Assignment Sheet 8

Ladder Schematics

ACR System Wiring Diagrams
Unit 15

Assignment Sheet 9—Draw Wiring Diagrams for a Condensing Unit and an Air Handler

Name ____ Overall Rating ______

Evaluation Criteria	**Rating**
Pictorial properly drawn	______
Ladder schematic properly drawn	______

Directions: Use the following procedure to complete a pictorial and then use the pictorial as a guide to complete a ladder schematic. Pictorial components and a blank page for a ladder schematic are on separate pages so you can keep the finished pictorial in full view to help you more easily draw the ladder schematic.

Procedure

1. Connect L_1 and L_2 on the disconnect switch to fuses.
2. Route power leads from fuses through the cable entrance in the outdoor condensing unit and connect to L_1 and L_2 of the contactor.
3. Connect T_2 on the contactor to one side of the compressor motor overload heater.
4. Connect the other side of the overload heater to R on the compressor motor.
5. Connect T_1 on the contactor to C on the compressor motor.
6. Connect the outdoor fan motor to T_1 and T_2.
7. Connect identified terminal of run capacitor to T_2.
8. Connect other side of the run capacitor to S on the compressor motor.
9. Connect one side of the start capcitor to the identified terminal on the run capacitor.
10. Connect the other side of the start capacitor to 1 on the potential relay.
11. Connect 2 on the potential relay to the other side of the run capacitor.
12. Connect 5 on the potential relay to T_1.
13. Connect 120V fuse to the blower interlock switch.
14. Connect the transformer primary to the other side of the blower interlock switch and neutral.
15. Connect the fan relay contacts in series with the blower interlock switch and the indoor fan motor.

Assignment Sheet 9

16. Connect the other side of the indoor fan motor to the neutral side of the transformer primary.

17. Connect all corresponding letters between the thermostat and the air handler terminal block.

18. Connect both corresponding letters between the transformer and the terminal block.

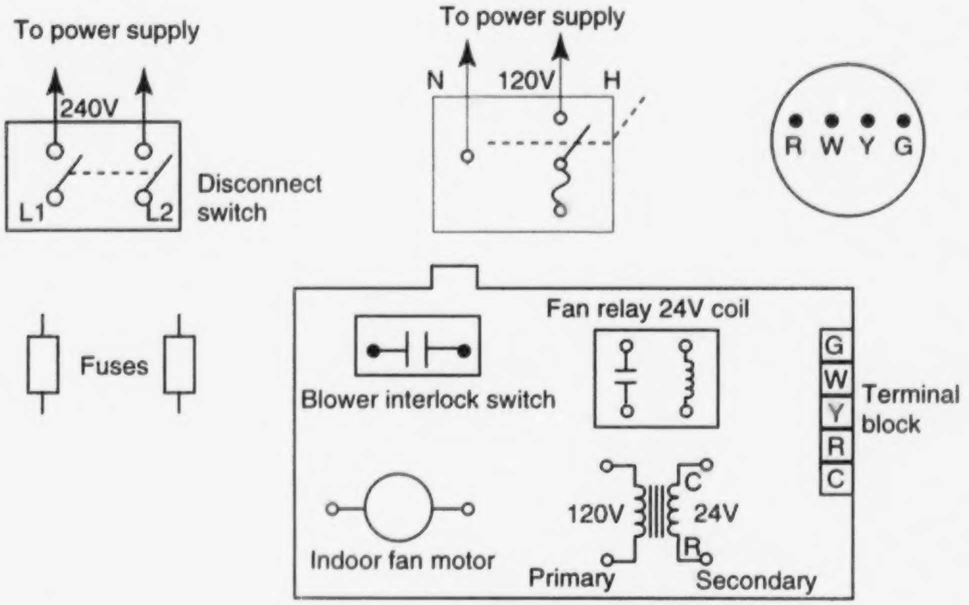
19. Connect C on the terminal block to one side of the contactor coil, using the cable entrance.

20. Connect the compressor overload contacts, the high pressure control and the low pressure control in series with Y on the terminal block and the other side of the contactor coil, using the cable entrance.

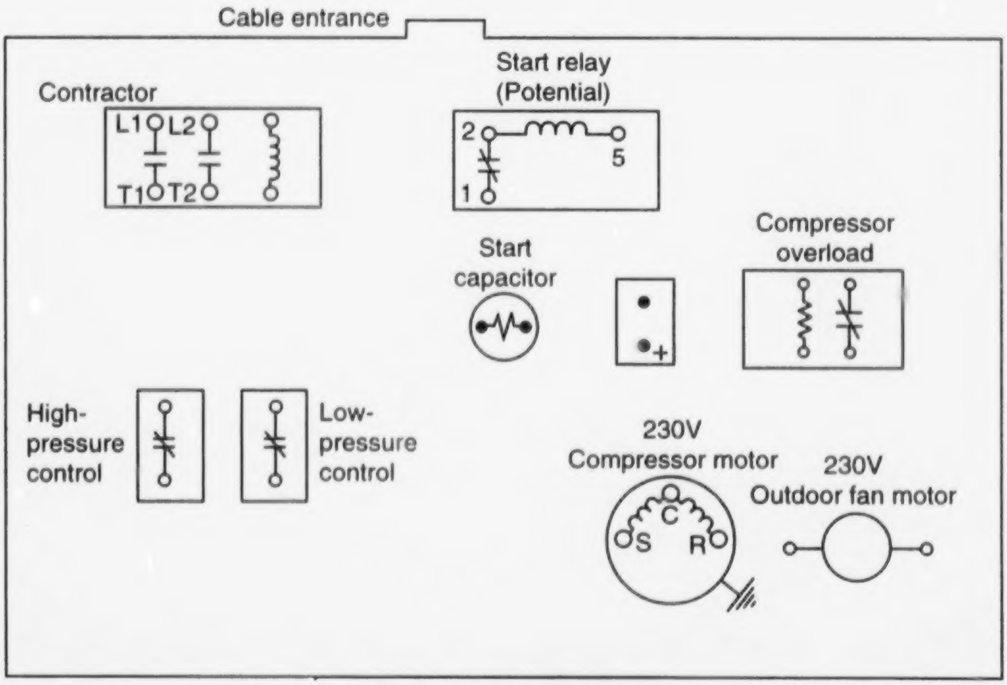
21. Connect the fan relay coil to C on the transformer and to G on the terminal block.

22. Reference your completed pictorial to draw a matching ladder schematic on the page provided.

Assignment Sheet 9


To power supply
240V
L1
L2
Disconnect switch
To power supply
N
120V
H
R
W
Y
G
Fuses
Blower interlock switch
Fan relay 24V coil
G
W
Y
R
C
Terminal block
Indoor fan motor
120V
24V
C
R
Primary
Secondary

Indoor Air Handler


Cable entrance
Contractor
L1
L2
T1
T2
Start relay (Potential)
2
5
1
Start capacitor
+
Compressor overload
High-pressure control
Low-pressure control
230V Compressor motor
C
S
R
230V Outdoor fan motor

Outdoor Condensing Unit

Assignment Sheet 9

Ladder Schematics

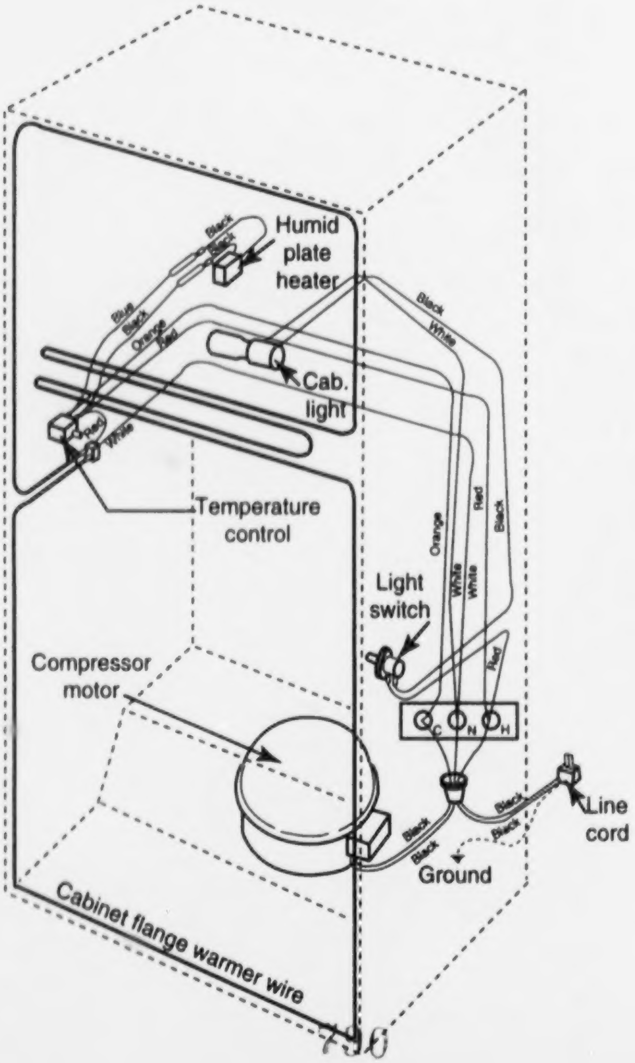
ACR System Wiring Diagrams
Unit 15

Assignment Sheet 10—Draw a Ladder Schematic for a Domestic Refrigerator

Name ______________________________ Overall Rating ______

Evaluation Criteria	**Rating**
Ladder schematic properly drawn	______

Directions: Use the following pictorial diagramas a guide to complete a ladder schematic. A separate page is provided for your ladder schematic so you can keep your pictorial in full view as you sketch.


Humid plate heater
Black
Black
Blue
Black
Orange
Red
Black
White
Cab. light
Red
White
Temperature control
Orange
White
White
Red
Black
Red
Light switch
C
N
H
Compressor motor
Black
Black
Black
Black
Line cord
Ground
Cabinet flange warmer wire

Assignment Sheet 10

Ladder Schematic

ACR System Wiring Diagram
Unit 15

Job Sheet 1—Observe a Domestic Refrigerator and Draw a Ladder Schematic of Its Electrical Circuits

Name ______________________________ Attempt Number ______

Date ______________________________ Overall Rating _________

Evaluation Criteria	**Rating**
System electrical circuits identified	______
Ladder schematic properly drawn	______

A. Tools and materials

Domestic refrigerator as selected by instructor
ACR technician's hand tools

B. Procedure

☐ 1. Make sure electrical power is disconnected from the refrigerator.

Note: Anytime the electrical power is disconnected from a refrigerator that has been operating, the doors should be left open to prevent the formation of mildew and offensive odors.

☐ 2. Remove any panels or covers necessary to locate the electrical components.

☐ 3. Check the back of the refrigerator and the backs of panels and covers for a pictorial wiring diagram.

☐ 4. Record make and model number:

Make: ____________________ Model number: ______________

☐ 5. Locate all the electrical loads.

☐ 6. Determine what is controlling each load.

Note: Loads such as mullion and perimeter heaters are usually on anytime there is electrical power to a refrigerator so there is no control in these circuits.

☐ 7. Draw a ladder schematic and label all the components.

☐ 8. Have your instructor check your ladder schematic.

☐ 9. Replace any panels or covers that were removed.

☐ 10. Clean up area and return tools to proper storage.

Comments: ____

ACR System Wiring Diagram
Unit 15

Job Sheet 2—Observe a Window Air Conditioner and Draw a Ladder Schematic of Its Electrical Circuits

Name ______________________________ Attempt Number ______

Date ______________________________ Overall Rating ______

Evaluation Criteria	**Rating**
System electrical circuits identified	______
Ladder schematic properly drawn	______

A. Tools and materials

Window Air Conditioner as selected by instructor
ACR technician's hand tools

B. Procedure

☐ 1. Make sure electrical power is disconnected from the air conditioner.

☐ 2. If the air conditioner is still in its cabinet, remove it.

☐ 3. Remove any panels necessary to locate electrical components.

☐ 4. Check cabinet and panels for a pictorial wiring diagram.

☐ 5. Record make and model number:

Make: ____________________ Model number: ______________.

☐ 6. Locate all electrical loads.

☐ 7. Determine what is contolling each load.

Note: Reference Assignment Sheet 3 for typical window air conditioner wiring.

☐ 8. Draw a ladder schematic and label all components.

☐ 9. Have your instructor check your ladder schematic.

☐ 10. Replace any panels that were removed.

☐ 11. If you removed the air conditioner from a cabinet, replace it.

☐ 12. Clean up area and return tools to proper storage.

Comments: ____

____

____

ACR System Wiring Diagram
Unit 15

Job Sheet 3—Observe a Heating/Cooling System With 24V Controls and Draw a Ladder Schematic of Its Electrical Circuits

Name ______________________________ Attempt Number ______

Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
System electrical circuits identified	______
Ladder schematic properly drawn	______

A. Tools and materials

Heating/Cooling System as selected by instructor
ACR technician's hand tools

B. Procedure

☐ 1. Make sure electrical power is disconnected from the system.

Note: A split system may have more than one power source.

☐ 2. Remove any panels necessary to locate electrical components.

☐ 3. Check inside the equipment and the backs of panels for wiring diagrams.

☐ 4. Record make and model number:

Make: ______________ Model number: ____________.

Make: ______________ Model number: ____________.

☐ 5. Locate all of the electrical loads.

☐ 6. Determine what controls each electrical load.

☐ 7. Draw a ladder schematic and label all the components.

Note: If system has more than one power source, you will have to draw a ladder schematic for each source.

☐ 8. Have your instructor check your ladder schematic(s).

☐ 9. Replace any panels that were removed.

☐ 10. Clean up area and return tools to proper storage.

Comments: ____

____

____